MODEL 4010

GAS DILUTION CALIBRATOR

OPERATIONS MANUAL

Sabio
INSTRUMENTS, INC.

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MODEL 4010 OPERATIONS MANUAL

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Section 1 Introduction

Users can easily perform gas dilution, ozone, and GPT calibrations with Sabio Instruments Inc.'s intelligent Model 4010 gas dilution calibrator. The Model 4010 was designed to set a new government and industry standard of quality and performance for gas calibrations. Enhanced with the latest technology, Sabio's Model 4010 Gas Dilution Calibrator is an uncomplicated and effective way to precisely control the dilution of gas standards for calibration of ambient air and source monitoring analyzers.

An easy-to-read display, with touch panel operation, user-friendly menu software and sturdy hardware amenities make the Model 4010 both highly practical and easy to operate. Each Model 4010 component was selected or designed with great care to meet Sabio's quality performance standards and government environmental agency goals and requirements.

User Benefits

Quality Construction. Sabio selected very high quality, inert valves for the source, permeation and dilution streams. The source and permeation oven valves wetted surfaces are manufactured with inert materials. To ensure the manifolds do not react with the gases, the manifolds are made of inert materials. Sabio minimized dead space in the valves and manifolds to assure fast rise times. A source purge-valve is standard for sweeping trapped gas out of the source manifold. Static mixers enhance homogeneous blending of diluent and source gases and the reaction chamber meets EPA requirements. Mass-flow controllers precisely meter all gas streams.

Modern technology means precision calibration. In combining superior software, components and materials, Sabio's Model 4010 is setting a new benchmark for precisely diluting gas standards.

Elemental design means no lengthy training period required. The design of the Model calibrator makes it easy for non-technical personnel with little or no specialized training to perform precise calibrations of gas analyzers.

A complete calibration system. The Model 4010 Calibration System makes use of embedded microprocessor technology to enhance the accuracy and control features of the calibration system. The Model 4010 is designed to be used manually, automatically or semi-automatically by remote control to conduct calibrations. The unit features an optional internal ozone generator. An optional permeation oven and UV absorption photometer are also available.

Versatile programming options. The calibrator has the capability to produce and store in memory 20 calibration sequences, with up to 20 levels of source/dilution in each sequence. Users employ the front panel membrane keypad or serial port to input calibration parameters. A bright, easy-to-read, 25-line x 80-character display shows calibration and system configuration information.

Additional features include continually updated display of dilution and source information, local and remote calibration control, eight-port output manifold with port connections for up to seven gas analyzers, and portable and 19-inch rack mounting options.

The Model 4010's precision ozone generator is suitable for use as a transfer standard for ozone calibrations or can be used for performing nitrogen dioxide calibrations by means of gas phase titration (GPT). The ozone generator eliminates the need for an additional ozone transfer standard to conduct audits or perform calibrations.

The Model 4010's ozone generator uses a mass flow controller in its ozone stream, thus eliminating pressure problems experienced by the competition. In addition, the ozone generator's advanced electronic circuitry and propriety photo detector enable the ozone generator output to be so stable and accurate that the need for a photometer is eliminated.

The internal UV absorption photometer option is a complete UV ozone analyzer that can be used independently for monitoring ozone production.

The Model 4010 internal or external permeation oven option is an effective tool for generating precise gas concentrations for calibrating a wide range of gas analyzers. The large oven capacity accommodates many types and sizes of permeation devices. An internal clean air supply, precise mass flow controller and temperature controller ensures a highly accurate gas concentration process.

Standard Features

- Embedded 386 CPU microprocessor, 55 button membrane key pad, 25 line x 80-character electroluminescent display and user-friendly, menu-driven software
- Serial communications ports and parallel printer port
- User digital inputs/outputs (24) for use as remote control inputs or status outputs
- Gas dilution system featuring the finest inert valves and mass flow controllers for control and precise metering of source and diluent gases

Optional Features

- Precision ozone generator
- Internal UV absorption photometer
- Internal permeation oven

The Model 4010 design exceeds the United States EPA calibration method requirements. Dilution components are calibrated with standards and test equipment traceable to the National Institute of Standards and Technology (NIST).

Model 4010 Gas Dilution Calibrator Specifications

Pneumatics:

- Flow accuracy ± 1.0% of full scale
- Flow repeatability ± 0.15% of full scale
- Flow linearity ± 0.5% of full scale

Diluent:

- Mass flow controller range 0 - 10 SLPM (Optional 0 - 20 SLPM)
- Input pressure 20 - 30 PSIG
- Port 1, normally air (Optional Port 2, user defined)

Source:

- Mass flow controller range 0 - 100 SCCM (Optional 0 - 20 SCCM, 0 - 50 SCCM, 0 - 200 SCCM, 0 - 500 SCCM, 0 - 1 SLPM. 0 - 2 SLPM)
- Optional second source mass flow controller
- Input pressure 15 - 30 PSIG
- Four gas cylinder input ports (Optional two additional ports)
- Source manifold purge port
- Optional external permeation oven input port
- Optional internal permeation oven
- Usable dilution ratio varies with flow controller selection, add a second source flow controller for wider dynamic range
- Solenoid valving for diluent, source and purge ports
- Eight calibration gas output ports
- Optional output solenoid valve
- GPT reaction chamber meets EPA requirements
- Attains 95% of Set Point in less than 60 Seconds
- Optional internal permeation dryer for diluent port 1
- Wetted surfaces are composed of stainless steel, Teflon, Peek or glass; all ports Swagelok or equivalent; Viton and Calrez seals

Internal Permeation Oven Option:

- Glass oven chamber approximate length 13.2 cm long, inside diameter 3.02 cm, volume 94 cm^3, opening diameter 2.54 cm
- Carrier gas preheated
- Oven operating temperature maintained within $\pm$ 0.1 ^oC of set point from 3 ^oC above ambient to 60 ^oC
- Warm-up time less than 30 minutes
- Nominal carrier flow of 100 SCCM maintained within 1% by precision mass flow controller
- Internal carrier air supply with inlet filter, high-efficiency coalescent filter and pollution scrubber canister
- Optional permeation tubes

Ozone Generator:

- Output range 0.05 - 1.0 PPM at 5 SLPM instrument flow (Optional extended output range 0.05 - 1 PPM at 10 SLPM instrument flow)
- Accuracy $\pm$ 2% of set point or $\pm$ 3 PPB at 5 SLPM
- Nominal ozone flow of 100 SCCM maintained within $\pm$ 1 SCCM by precision flow controller
- UV lamp maintained at 50 $\pm$ 0.1 ^oC
- Optional UV optical servo control loop
- Optional UV absorption photometer

Internal UV Absorption Photometer Option:

- Ozone monitoring ranges 100 PPB to 20 PPM full scale
- Linearity $\pm$ 1 PPB or $\pm$ 1 percent of full scale, whichever is greater
- Precision $\pm$ 1 PPB
- Lower detectable limit 0.8 PPB
- Zero drift for 24 hours and 30 days less than 1 PPB
- Span drift for 24 hours and 30 days less than 0.5 percent of reading
- Lag time less than 10 seconds
- Rise and fall time of 95 percent of final reading less than 60 sec at 500 SCCM sample flow rate
- Nominal flow rate of 500 SCCM monitored by mass flow meter
- Teflon inlet filter

- Internal sample vacuum pump
- Recorder and data acquisition system analog outputs
- Operating temperature 5^{o} - 40 ^{o}C

Calibration Definitions:

- Twenty user defined calibration sequences with up to 20 points per sequence
- Calibrations may be gas blends, ozone or GPT
- Two diluent gas definitions and 20 source gas standard definitions
- Twenty timer-driven calibration routines that perform predefined calibration sequences on a calendar of events

Operation Modes:

- Manually through use of print panel 55-button membrane keypad and display, external user supplied keyboard or optional RS232 serial ports
- Automatically by remote contact closures, internal timer or serial ports

Electronics:

- Industry standard 25 MHz 386 CPU; flash memory for storage of software and user configuration; battery-backed real-time clock; 32-bit floating point math computations; capacity for future enhancements
- Fifty-five button membrane keypad, 25-line X 80-character (640 X 400 pixel graphics) electroluminescent display or color display
- Twelve bit resolution on servo control components (optional 16-bit analog input resolution)
- Status input/output board provides 24 programmable status I/O bits for control and monitoring of calibrator functions

- Optional solenoid drivers for interfacing with six 3 watt 24 VDC instrument calibration solenoids
- Two serial data communications ports
- Centronics parallel printer port
- External PCAT keyboard printer port
- Heavy duty universal input power supply and AC line filter

- Optically isolated power drivers
- PWM servo loops for precise control of UV lamp intensity and temperature levels

Electrical:

- Standard 96 - 264 VAC, 150 - 300 VA, 50/60 Hz operation
- Compressed air source control circuit provides switched 5 VDC, 12 VDC or 24 VDC

Mechanical:

- Size 8.75" (22.2 cm) H X 17" (43.2 cm) W X 20" (50.8 cm) D, size varies with rack mount kit and other options
- Average weight 40 lbs. (18.1 kg)

Miscellaneous:

- Temperature 5 - 40 ^{O}C
- Automatic restart on power up
- Warm-Up time less than 30 minutes
- Diagnostic routines for system calibration, checkout and leak testing
- Accessories and Options:
- Model 1001 or Model 1001P Compressed Air Source
- Model 2500 Permeation Unit
- Rack mount kit for 19" (48.3 cm) equipment racks
- High-impact plastic transport case
- Flow calibration standard

Specifications subject to change without notice

Section 2 Getting Started

This section introduces the customer to the Model 4010 and presents a few guidelines for getting started using the unit.

Unpacking and Power Application

Remove the Model 4010 from its shipping container and check the unit for damage. Contact the shipping company immediately if the unit sustained damage in transit. Check the packing list to verify that all items were received. Retain the original shipping container for warranty returns.

Temporarily place the unit on a table or counter top in a convenient spot for easy access to the front control panel. Locate the power cable and connect it to the rear panel power receptacle. Plug the other end of the power cable into a suitable AC power outlet.

Start-Up

On most Models of the 4010, the power switch is located on the lower right hand corner of the rear panel next to the power cord inlet connector. Some units may have a power switch located on the lower right hand corner of the front panel. Depress the rocker switch to energize the unit.

The display should illuminate in a few seconds and initialization messages should appear on the display. In approximately one minute the main menu screen should be displayed.

When under power, the Model 4010 pneumatics and electronics will begin their warming sequence.

Standby Operation Upon Power Up

Upon application of power to the Model 4010, the unit defaults to Standby Mode. In this mode, the Model 4010 is ready to receive user commands from the front panel or external keyboard, execute preprogrammed calibration sequences, accept commands from the RS232 serial communications ports or invoke sequences based on status information received from the status input/output ports.

User Interface

After the Model 4010 has finished it's power-up sequence, the screen shown in Figure 2-1 will be displayed on the 4010's front panel. The operation of the Model 4010 is similar to operation of many popular Windows applications. The front panel touch buttons are used in conjunction with the display when entering Model 4010 commands. The touch buttons are active at all times when the unit is under power. Section 3, "System Operations", describes in more detail general guidelines for operating the Model 4010.

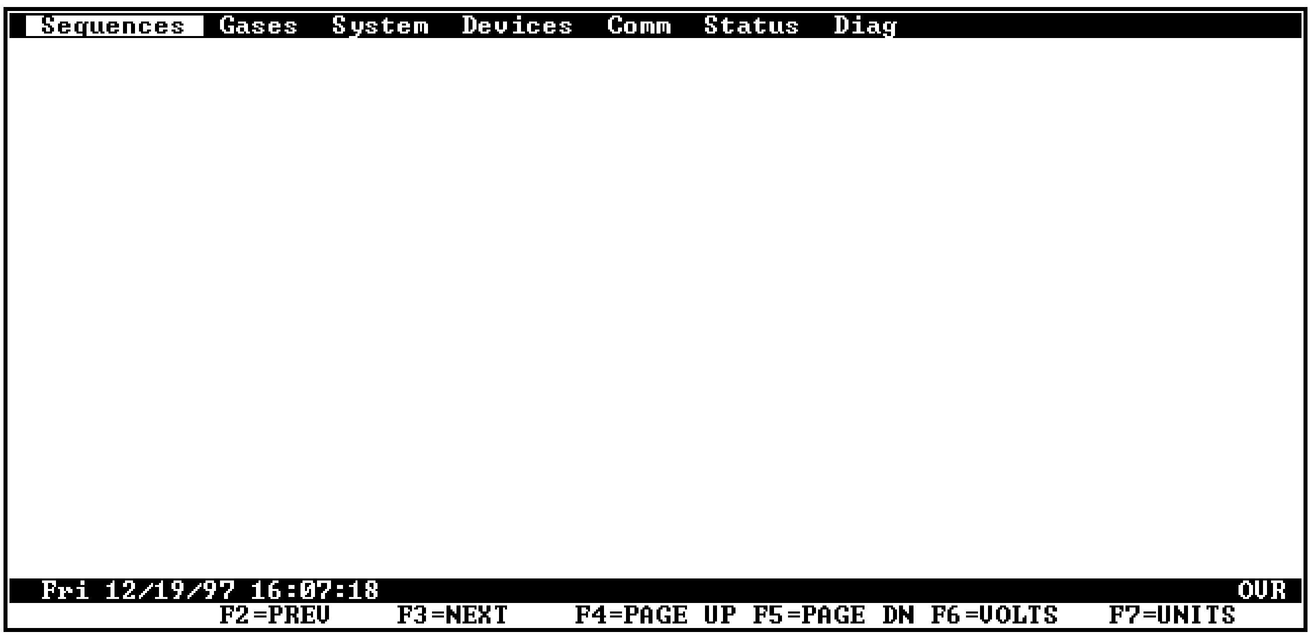


Figure 2-1 The Main Screen

Initial Configuration of the Model 4010

Before the Model 4010 can perform calibrations, it must be configured for the intended application. Following is the list of tasks that must be accomplished in order to place the unit in proper working order.

[1] Set the Model 4010's time and date to local time as described in the Subsection "Setting the Time and Date" in Section 6.

[2] Select the source gas and diluent gas. This is covered in the "Installation" section of the manual which begins on page 4-1.

[3] Determine source and diluent port usage on the rear panel of the Model 4010. This is covered in the "Installation" section of the manual which begins on page 4-1.

[4] Set up the 4010 for your specific calibrations. The "Model 4010 Calibration Set-up" section, starting on page 6-1, covers this topic.

[5] Verify and/or calibrate the flow controllers and the ozone generator. This topic, covered in the section titled "Calibrating Model 4010 Components", starts on page 8-1.

System Operation and Maintenance Precautions

Care should be taken to leave factory set parameters unchanged. Altering factory parameters can result in improper operation or even damage to the unit. Improper use of the diagnostic routines can also result in damage to the Model 4010.

When performing maintenance on the Model 4010, Power should be removed. Tools and small loose parts could cause damage to the unit if they come in contact with electrical circuits.

Anti static procedures should be used at all times when working with electronic components.

Section 3 System Operation

This section presents general information about the operation of the Model 4010 Calibration System.

Front Panel Guide

The Model 4010 front panel consists of a twenty-five line by eighty character electroluminescent or color display, an optional power switch and fifty five buttons for system operation. A drawing of the 4010's front panel is shown in Figure 3-1.

The front panel buttons are used for entering commands and information into the Model 4010. Provision is also made to support a standard IBM PC compatible PS2 style keyboard (which plugs into the rear panel). If an external keyboard is used, each of the front panel buttons have equivalent keys. In addition, there are several shortcuts available on an external keyboard that are impractical or unavailable from the front panel.

Following the front panel drawing is a listing of the 4010 front panel buttons and their functions. If the equivalent external key is not obvious from the button name, it is indicated in parentheses.

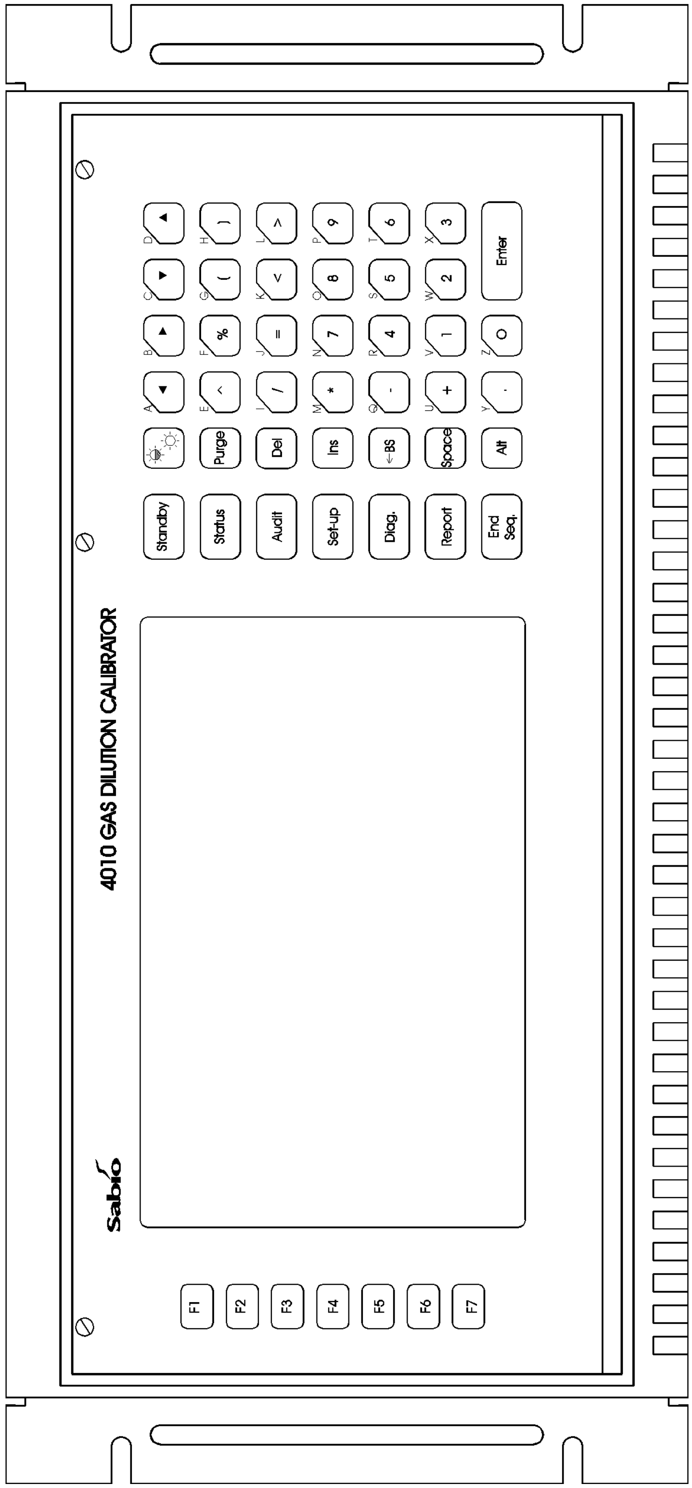


Figure 3-1 The Model 4010 Front Panel

Button	Description
Function Buttons:	
F1 - F7	Function key or button usage varies somewhat throughout the Model 4010 software application. The most common usage follows. Their active usage is given on the bottom status line of the application. Generally speaking, buttons F1 - F5 are used consistently throughout the application.
F1	F1 is reserved for future use and currently has no function.
F2 (Shift TAB)	F2 functions as a Back Tab button for moving backward from field to field.
F3 (TAB)	F3 functions as a Tab button for moving forward from field to field.
F4 (Page Up)	F4 functions as a Page Up button to move to the previous page or screen.
F5 (Page Down)	F5 functions as a Page Down button to move to the next page or screen.
F6	The F6 button often operates as a toggle button when machine status is displayed. It allows the user to select whether system monitor and control signals are viewed in engineering or voltage units.
F7	The F7 button often operates as a toggle button when machine status is displayed. It allows the user to change the engineering units in which numeric values are displayed and entered.

Button	**Description**
<u>*Special Function Buttons:*</u>	
Standby (Home)	In most instances the standby button is used to bring the user back to the main menu and place the Model 4010 in standby mode to await further commands.
Sun Button	The sun button is used to illuminate the display screen or blank the display screen. In normal mode, the button is pressed to illuminate the display screen and in alternate mode, pressing the button invokes the screen saver to blank the screen.
Status (F8)	The status button is used to obtain updated status information about the operation of the calibrator.
Purge (!)	The purge button momentarily activates the purge valve for flushing calibrator source manifold pneumatics.
Audit (F7)	This button is used to place the calibrator in run calibration sequence mode. If a sequence is active, the user will be returned to the "Select a Point" screen to change points.
Set-up (F10)	This button is used to initiate the setup of calibration sequences.
Diag (F11)	This button is normally used to activate the diagnostics selection menu. If a status screen is active when the Diag button is pressed, however, it causes Debug Mode to be selected, allowing control values in the status screen to be changed.

Report (F12)	This button is used to output the current screen contents to a printer attached to the parallel printer port.
End Sequence (Esc)	This button serves as an "Escape" key, backing out of edit screens and menus. When in standby mode, it is also terminates calibration sequences that are under way.

Button	**Description**
Cursor Control Buttons:	
Left Arrow	This button is used to move the cursor to the left.
Right Arrow	This button is used to move the cursor to the right.
Down Arrow	This button is used to move the cursor down or to scroll down.
Up Arrow	This button is used to move the cursor up or scroll the display up. On some occasions it may be used to move to the previous menu item.
Edit Buttons:	
DEL	This is the character delete button.
INS	This is the character insert button. It toggles the edit functions between insert mode and overtype mode. When the edit function is in insert mode, the INS message is displayed on the status bar in the lower right hand portion of the screen. Overtype mode is active when the OVR message is displayed on the status bar.

<-BS This is the back space button.

Space This is the space character button.

Enter This button is used to register field edits, select a menu item and move to the next or previous menu level. The large Enter registers actuation by pressing the left or right side of the button.

Button **Description**

Keypad Shift Button:

Alt The Alt button toggles the alpha/numeric buttons between alpha characters (those displayed in the upper left corner of the button) and the numeric or special function.

An ALT message is displayed on the status bar in the lower right hand portion of the screen when the alternate keys are active.

Other Alpha/Numeric Buttons The remaining buttons are used for normal alpha/numeric data entry.

Special External Keyboard Keys:

ALT-D This key toggles debug mode on or off. When in Debug mode, control values in the status screen may be changed.

ALT-X Exit to DOS.

ALT-M Check memory. The available memory is displayed on the status line.

ALT-U	Change the engineering units for the selected field.
ALT-V	Toggle the screen between voltage and engineering units.

Button	**Description**

Special External Keyboard Factory Test Keys:

--- CAUTION ---

The following special keys are normally used only at the factory for testing purposes. Improper use of these functions or leaving the 4010 is a test mode could result in a malfunction of the unit.

ALT-Q Quick mode.	This special test mode is used for testing sequence timing. When in quick mode, each minute in a sequence is equal to one second.
ALT-H Fake Hardware.	This special test mode is used at the factory for software testing. When fake hardware is selected, the normal 4010 hardware is bypassed and simulated in software.
ALT-W	Analog input averaging mode. This function is used for factory testing and allows four analog input processing options to be selected:

No Z/S Adjust	The automatic zero and span adjustments are disabled.
No Averaging	The rolling average that smoothes the analog input data is disabled.
No Avg or Z/S	Both averaging and automatic zero/span adjustments are disabled.

Normal	Normal mode with averaging and zero/span adjustment.

Main Screen Layout

The Model 4010's main screen, displayed after the power up sequence has been completed, allows operator interaction using a familiar windows-style interface. Figure 3-2 is an example of the Main Screen as it would appear when setting the system time and date.

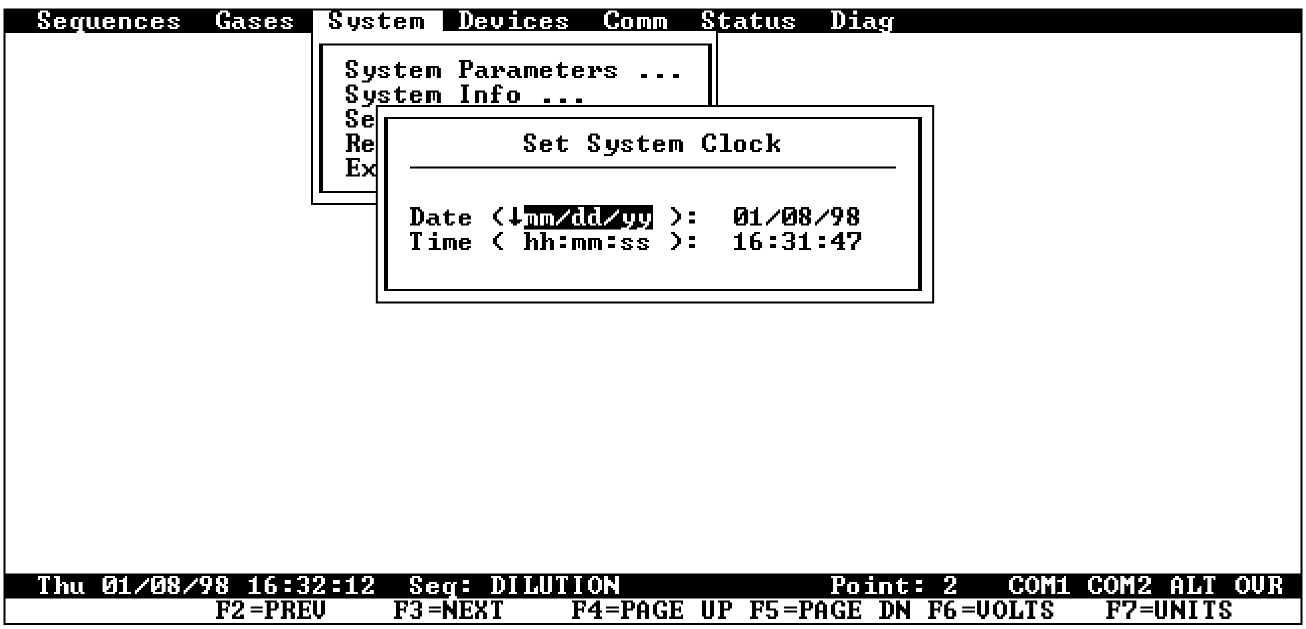


Figure 3-2 The Main Screen

The main screen consists of four parts: the menu bar at the top, a status line near the bottom, a function key line at the bottom and a large central area for displaying windows and screens.

The menu bar at the top supports drop-down menus and sub-menus. To select an item, move the selection highlight with the arrow keys to the item of choice and then press the enter button. The end sequence (escape) button is used to exit or abort the current operation or to back up through the menus.

If an external keyboard is used or if the 4010 is being operated remotely using terminal mode, a quicker way of selecting menu items is available. Each menu or sub-menu item has a "shortcut" letter associated with it. By entering the shortcut letter when a menu is displayed, the associated menu item will be selected. There is no need to press Enter after a shortcut letter, so entering a string of shortcut letters is a quick way to navigate a menu path.

Since the display does not support gray-scales, the shortcut letters are not evident from the front panel, but they are usually the first letter of the menu item. For example, by entering "SE" on an external keyboard, the **S**equence **E**dit screen will be selected.

When operating the 4010 via a serial port in terminal mode, the shortcut keys are indicated as a different color, as shown in the figure below.

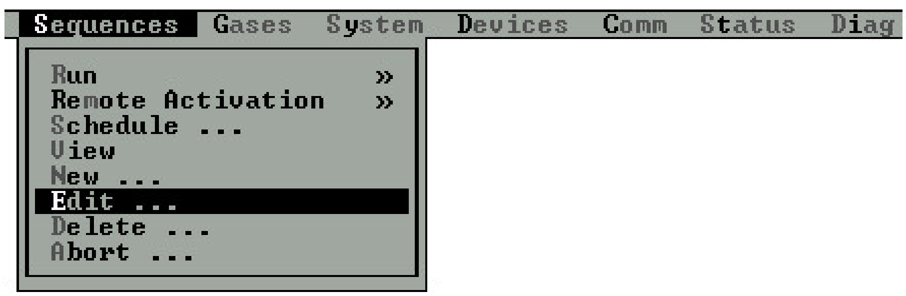


Figure 3-3 External Keyboard Shortcuts in Terminal Mode

Near the bottom of the screen, a status line displays information about the current state of the 4010. The following information may be found on the status line:

Time and Date — The current time and date is always displayed at the left side of the status line. The format in which the date is displayed may be changed from the Set Time and Date screen under the System menu.

Status message — To the right of the status line, a short status message may be displayed. This message might indicate that a certain mode of operation has been selected or, if a sequence is active, will indicate the active sequence name and point.

COM1, COM2	To the right of the status message area, a COM1 and/or COM2 indicator will appear when the associated communication port is active.
ALT	If the ALT key is pressed on the front panel, an "ALT" indicator will be shown on the status line. Pressing buttons on the front panel while in ALT mode causes the alternate key definitions (indicated to the upper left of the key) to be selected.
OVR/INS	To the far right of the status line the "OVR" indicator is usually shown, indicating that the unit is in overwrite mode. Pressing the Ins button will change this indicator to "INS" indicating that insert mode has been selected.

The bottom line of the screen displays the functions associated with the seven function keys, F1 through F7.

The remaining portion of the screen is used to display menus setup screens and system status information.

A screen saver program will blank the screen if there is no user input from the keypad/keyboard or serial communications ports. To bring the screen back, press the sun button.

Main Menu Topics

The current Menu is broken up into seven main topics: Sequences, Gases, System, Devices, Comm, Status and Diag. A brief description of each main menu item follows. Note the underlined letter in each menu name, which represents the shortcut key that is available when using an external keyboard.

Sequences The Sequences menu item invokes screens for defining, editing, viewing, deleting, running and aborting calibration sequences.

Gases The Gases menu item invokes screens to define gas table items, gas standards and assign gas standards to ports. Screens are provided for defining, editing, viewing, and deleting these items.

System The System menu is used to set-up system parameters, set the clock, restart the program and exit to the DOS operating system.

Devices The dilution unit, ozone generator and the optional perm oven and photometer are covered under the Devices topic. Options, parameters, and calibration routines are provided for these devices.

Comm The Communications topic is used to configure the serial communications ports for remote terminal communications or command mode operation.

Status The Status option is used to display status information for the system when it is idle or while calibration routines are running.

Diag System diagnostic routines are made available by the Diag menu option.

Using the 4010 Screens

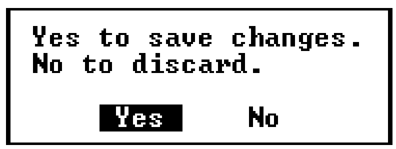
Most menu selections result in a screen being activated. Several types of screens may be displayed while operating the 4010:

Error Popup

If an error occurs while operating the 4010, an Error Popup containing the error message will be displayed. The Error Popup will prevent any other actions until it is acknowledged by pressing the Enter button.

Confirmation Popup

Sometimes, when a critical operation is performed, the 4010 will pop up a box asking if the user <u>really</u> wants to do that. For example, when the End Sequence button is pressed after something has been changed in an Edit Screen, the following box will be popped up:



Confirmation Popups remain active, preventing any other actions, until the user responds by positioning the highlight over the appropriate response and pressing Enter. If an external keyboard is being used, the user can respond simply by pressing "Y" or "N". Pressing End Sequence causes the Confirmation Popup to disappear, returning the user to the original screen without changing anything.

View Screen

Some screens are displayed for informational purposes only. View Screens generally allow configuration information to be viewed, but don't allow the contents to be altered. View Screens may be removed by pressing the End Sequence key.

Status Screen

Status Screens contain information about the current operation of the 4010. Information presented in these screens is updated each second. Status Screens are removed by pressing the End Sequence key.

Edit Screen Edit screens allow the user to enter or change information. Pressing Escape after making a change to an Edit Screen will cause a Confirmation Popup to appear, asking if the screen should be saved.

Edit Screens

Edit screens are the main mechanism by which a user configures the 4010. These screens are usually called up by selecting menu items associated with setup functions and contain one or more "fields" for entering or changing data.

Using Edit screens is very simple. Usually, the F2 (Shift-TAB) and F3 (TAB) keys are used to move the cursor to the field that contains the data to be entered or changed. Alternatively, the Enter button may be used to move to the next field. After entering the appropriate information, the Enter button can be pressed or the cursor moved to another field in order to confirm the change. If inappropriate information is entered into the field, an Error Popup will be presented when an attempt is made to confirm the change.

Pressing the End Sequence button will exit the Edit Screen. The contents of the screen will be validated at this time and an Error Popup will be presented if something is wrong. If there is a validation error, the Error Popup must be acknowledged and the error corrected before continuing. If there are no errors, a Confirmation Dialog will be presented asking if the changes should be saved or discarded. Selecting "Yes" will exit the screen and save the changes.

There are a number of different types of data entry fields, each intended for entering or changing a different type of data. The first page of the Edit Sequence screen, shown in Figure 3-4, contains most of the data entry field types.

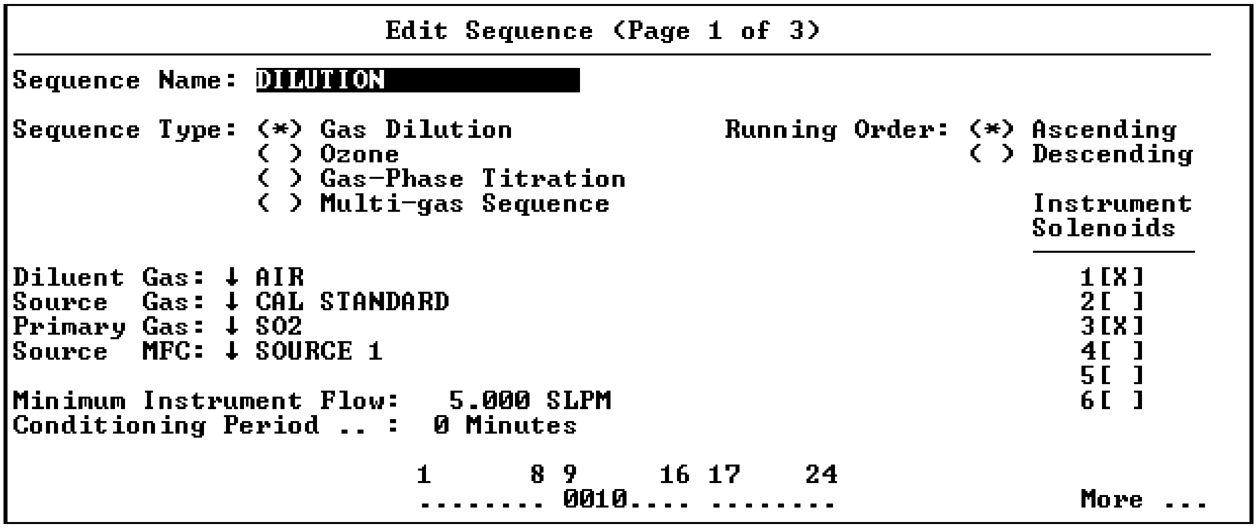


Figure 3-4 Examples of Data Entry Fields

Following are descriptions of the various data entry fields that may be encountered in an Edit Screen, along with examples taken from the Edit Sequence screen.

Text Edit Field **Sequence Name: DILUTION**

The Text Edit Field allows alpha-numeric information such as sequence names, gas names, etc. to be entered. The cursor may be moved around within a field by using the left and right arrow buttons. The Del and BS buttons may be used to delete characters while the Ins button will toggle the overwrite/insert state, determining whether the entered text will overwrite or be inserted into existing text.

Integer Edit Field **Period .. : 10 Minutes**

The Integer Edit Field allows whole numbers to be entered.

Number Edit Field **Flow: 5.000 SLPM**

The Number Edit Field allows floating-point numbers with decimal points to be entered. Some Number Edit Fields have engineering units associated with them. If so, the units can often be changed by pressing the F7 key to toggle through the available unit options. Changing the units automatically causes the contents of the field to be recalculated and presented in terms of the new units. This allows numeric information to be entered or viewed in alternate units of measure.

If a number is too large to fit in the Number Edit Field, the field will be filled with "#" characters.

Digital I/O Field

```
1      8 9     16 17    24
........ 0010.... ........
```

Digital data, such as sequence status output or remote control input assignments may be entered in Digital I/O Fields. These fields are useful for entering groups of bits and usually represent from two to 24 digital I/O bits. If there are more that 8 bits in a field, they are separated into groups of eight for clarity. The bit numbers are usually indicated above the Digital I/O Field for reference.

Bits indicated by a "." (decimal point) have been assigned to other uses (from the Digital I/O Group Assignments screen) and are not available for entry or editing. Bits available for editing are indicated either by a "1" (active) or "0" (inactive).

Bits may be activated by entering "1", "Y" or "+", deactivated by entering "0", "N", "-" or Space or toggled by entering a decimal point. When a bit is changed with a "1", "0", "Y", "N" or Space, the cursor automatically moves to the next bit position. When changed with a "+", "-" or ".", the cursor remains in the same position.

Radio Buttons

```
Running Order: (*) Ascending
               ( ) Descending
```

Radio Buttons allow an item to be selected from a list of options. Radio buttons are presented in groups of two or more; each group being considered as a single field. The arrow keys may be used to move between the radio buttons and the Enter or Space button used to select it. The selected item is indicated by an "*" inside the parenthesis. Selecting a radio button de-selects all other buttons in the same group. Some radio buttons are intended for answering yes/no questions. These Radio Buttons may be selected by entering "Y" or "N".

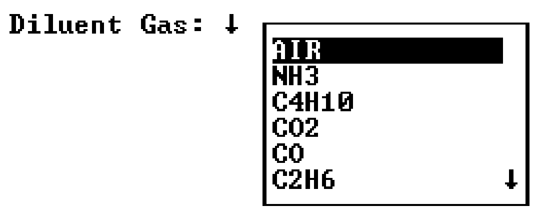
Check Boxes

```
Instrument
Solenoids
----------
  1[X]
  2[ ]
  3[X]
```

Check Boxes are similar to Radio Buttons in that they allow options to be selected, however any number of Check Boxes in a group may be selected. Check Boxes are selected by entering "1", "+", "Y" or "X", de-selected by entering "0", "-" or "N" or toggled by entering "." or Space. Though they may be presented in groups on the screen, each Check Box is considered to be a separate field.

Drop-down List Boxes

Drop-down list boxes appear similar to Text Edit Fields, however a down-arrow (↓) to the left of the field indicates that a selection list may be dropped by pressing the down arrow or Enter button. When dropped, the Drop-down List Box presents a list of options, as shown below:



The Desired item may be selected from the list by using the up and down arrows to position the cursor and then pressing Enter. Arrows to the right of the list indicate when there are more items below or above the visible area of the box.

Section 4 Installation

This section describes the initial installation of the Model 4010 and presents considerations for improving the quality of calibrations.

Placement

The Model 4010 may be mounted in a 19 inch equipment rack or set on a laboratory counter top or other bench. Use extreme care in its placement. Allow at least 2 inches of clearance on the sides. The lower front panel bezel of the unit contains the air intake vents and the rear panel Electronics Unit contains the exhaust fan that must remain unobstructed at all times. In rack mount installations, adequate air circulation must be maintained.

--- CAUTION ---

Do not install the Model 4010 near devices which produce large magnetic or electric fields. The calibrator and air source should not be installed immediately next to each other.

Environment

Room temperature must be maintained in the range of 10 - 30^{o} C (20 - 30^{o} C to meet EPA requirements). Under no circumstances should room or rack temperature be allowed to exceed 40^{o} C. Improper installation may greatly decrease the reliability of the Model 4010 and associated equipment. Adequate clearance should be maintained on all sides of the unit to ensure proper air circulation and proper operation.

The unit should be operated in a dust free environment to ensure that dust and lint do not build up on delicate electronic components. Air intake and exhaust vents should be cleaned on a regular basis to maintain adequate airflow.

Source Gas Cylinder Selection

When choosing source gas cylinder concentrations keep in mind the following:

- The standard Model 4010 flow controller ranges are a 0 - 100 cc/min for the source gas flow controller and a 0 - 10,000 cc/min for the diluent gas flow controller.
- Optional Model 4010 flow controller ranges are typically 0 - 50 cc/min for the source gas flow controller and 0 - 20,000 cc/min for the diluent gas flow controller.
- Typical dilution ratios for the standard flow controller ranges (100 cc/min source flow controller and 10,000 cc/min dilution flow controller) are approximately 40:1 to 2,001:1 when a minimum instrument flow of 4,000 cc/min is delivered to the Span Gas Output ports.
- The low end of each flow controller (usually 5% of maximum flow) is not used.
- The dilution ratios vary with flow controller combinations, flow controller curves, and instrument flow requirements.
- Stable gas blends are acceptable.

The calculation for a unit equipped with a 10,000 cc/min diluent flow controller, a 100 cc/min source flow controller and a minimum of 4,000 cc/min instrument flow are as follows:

```
Desired Instrument Span Points: 50 - 490 PPB

Minimum Diluent Flow = 0.05 * 10,000 cc/min
                     = 500 cc/min

Maximum Diluent Flow = 1.00 * 10,000 cc/min
                     = 10,000 cc/min

Minimum Source Flow  = 0.05 * 100 cc/min
                     = 5.0 cc/min

Maximum Source Flow  = 1.00 * 100 cc/min
                     = 100 cc/min
```

$$\text{Minimum Dilution Ratio} = \frac{100\ \text{cc/min}}{100\ \text{cc/min} + 3{,}900\ \text{cc/min}}$$

$$= 2.5 * 10^{-2} \text{ or } 40:1$$

Note: Diluent Flow = 4,000 cc/min - 100 cc/min
= 3,900 cc/min

$$\text{Maximum Dilution Ratio} = \frac{5\ \text{cc/min}}{5\ \text{cc/min} + 10{,}000\ \text{cc/min}}$$

$$= 5.00 * 10^{-4} \text{ or } 2{,}001:1$$

Note: Diluent Flow is maximum and Source Flow is minimum

Desired Instrument Span Points: 50 - 490 PPB

Concentration Range for 50 PPB Point:

50 PPB * 40.00 = 2,000 PPB or 2.00 PPM
50 PPB * 2,001 = 100,050 PPB or 100.05 PPM

Concentration Range for 490 PPB Point:

490 PPB * 40.00 = 19,600 PPB or 19.6 PPM
490 PPB * 2,001 = 980,490 PPB or 980.49 PPM

From the above calculation, a good choice would be for the gas cylinder concentration to be in the range of 19.6 PPM to 100.05 PPM. If a gas cylinder concentration of 60 PPM was chosen then the following range of concentrations could be produced:

Low Point = 60 PPM * 5.00 * 10^{-4}
= 30.00 PPB

High Point = 60 PPM * 2.50 * 10^{-2}
= 1,500 PPB

If a gas blend is desired, similar calculations are required for each of the blends. For further information, please contact the factory.

Permeation Tube Selection

When choosing permeation tube permeation rates keep in mind the following:

- Nominal flow through the Model 4010 Permeation Oven is 94 cc/min and the nominal oven operating temperature is 40^{o} C. The volume of the Model 4010 permeation oven is approximately 94 cc. The recommended flow through the permeation oven is a minimum of one volume change per minute.
- The standard Model 4010 diluent flow controller range is 0 - 10,000 cc/min. Optional Model 4010 diluent flow controller range typically 0 - 20,000 cc/min.
- Typical dilution ratios for the standard diluent flow controller ranges and permeation oven flow are approximately 21.28:1 to 107.38:1 when a minimum flow of 2,000 cc/min is delivered to the Span Gas Output ports.
- The top low end of each flow controller (usually 5% of maximum flow) is not used.
- The dilution ratios vary with flow controller combinations, flow controller curves, permeation oven flow and instrument flow requirements.
- Multiple tubes or tube types may be placed in the permeation oven. Consult your permeation tube manufacturer for specifics on tube compatibilities.

The calculations for a Model 4010 equipped with a 10,000 cc/min diluent flow controller, a Model 4010 Permeation Oven with a 94 cc/min source flow and a minimum of 2,000 cc/min instrument flow are as follows:

Desired Instrument SO_2 Span Points: 100 - 400 PPB

Minimum Diluent Flow = 0.05 * 10,000 cc/min
= 500 cc/min

```
Maximum Diluent Flow = 1.00 * 10,000 cc/min
                     = 10,000 cc/min

Permeation Oven Flow = 94 cc/min

                                   94 cc/min
Minimum Dilution Ratio = -----------------------
                         94 cc/min + 1,906 cc/min
```

$= 4.7 * 10^{-2}$ or 21.28:1

```
Note: Diluent Flow = 2,000 cc/min - 94 cc/min
                   = 1,906 cc/min


                                  94 cc/min
Maximum Dilution Ratio = -------------------------
                         94 cc/min + 10,000 cc/min
```

$= 9.31 * 10^{-3}$ or 107.38:1

Note: Diluent Flow is maximum

Desired SO_2 Instrument Span Points: 100 - 400 PPB

Oven Output Concentration Required for 100 PPB Point:

100 PPB * 107.38 = 10,738 PPB or 10.738 PPM

Maximum Concentration That Model 4010 Can Generate:

10.738 PPM / 21.28 = 504.61 PPB

From the above calculation, a good choice would be for the Model 4010 Permeation Oven to generate a gas concentration of 9 PPM to ensure that the 100 PPB point can be generated. If a permeation tube was chosen to generate a gas concentration of 9 PPM, then the following range of concentrations could be produced:

Low Point $= 9 \text{ PPM} * 9.31 * 10^{-3}$
$= 83.79$ PPB

$$\text{High Point} = 9\ \text{PPM} * 4.7 * 10^{-2} = 423\ \text{PPB}$$

To calculate the permeation rate in ng/min for an SO_2 permeation tube, perform the following calculations:

$$\text{Permeation Rate, } P = \frac{FC}{K_m} = \frac{94 * 9}{0.382}$$

$$= 2{,}214.7\ \text{ng/min}$$

Where F = Permeation Oven Flow Rate, cc/min
C = Output Concentration, PPM
K = Molar Constant for SO_2 from Figure 4-1

For this application a 2,215 ng/min at 40^{o} C SO_2 permeation tube would be purchased.

Table 4-1 Common Molar Constants

Gas	Formula	K_m
Ammonia	NH_3	1.439
Hydrogen Sulfide	H_2S	0.719
Nitrogen Dioxide	NO_2	0.532
Sulfur Dioxide	SO_2	0.382

If a gas blend is desired, similar calculations are required for each of the blends.

For further information, please contact the factory.

Diluent Selection

When choosing diluents keep in mind the following:

- For a clean air source, the recommended choice is a Sabio Engineering Model 1001 Compressed Air Source.
- The rack mountable self contained Model 1001 provides 22 liters/min of air at 25 psig, a surge/condensate tank, regulated output with pressure relief valve, 0 - 60 psig output gauge, first stage air cleanup, brushless/oil free compressor, and an automatic condensate purge on power down. A catalytic oxidizer and internal permeation dryer are also available.
- An alternate air source should be able to provide clean air with a regulated output pressure of 25 - 30 psig at a minimum flow of 20 liters/min for a Model 4010 equipped with a 10,000 cc/min diluent flow controller. A Model 4010 equipped with a 20,000 cc/min flow controller requires a minimum of 22 liter/min air output at 25 psig pressure.
- Gas cylinders with clean diluents such as air or nitrogen are also acceptable, however if the ozone generator is used, the diluent must be air with the normal percentage of oxygen. A regulator should be attached to the gas cylinder to regulate the flow to 20 - 25 psig.

Source and Diluent Port Usage

- Source gas cylinders can be connected to Source 1 through Source 4 and optionally Source 5 through Source 6 Gas Input Ports.
- An optional Model 4010 or Model 2500 Permeation Oven may be connected to the optional External Perm. Input Port.
- The air diluent should be connected to the Diluent 1 Input Port. Air connected to this port must be well filtered of particulates, dry and free of low level pollutants.
- Gas cylinder diluents should be connected to the optional Diluent 2 Input Port.

Dilution Calibrator Pneumatic Connections

A rear panel drawing of the Model 4010 Dilution Calibrator is shown in Figure 4-1. Teflon or stainless steel tubing should be used for pneumatic connections. Teflon tubing is preferred for Ozone analyzer connections.

The compressed air source (Sabio Engineering Model 1001) is normally connected to the Diluent 1 Input Port. Connect the compressed air source input port to the system sample manifold. The air source must be capable of supplying a constant pressure of at least 25 psig. An alternate diluent (must be clean and dry) may be connected to the Diluent 2 Input Port. **Diluents must be regulated to prevent damage to the Model 4010.**

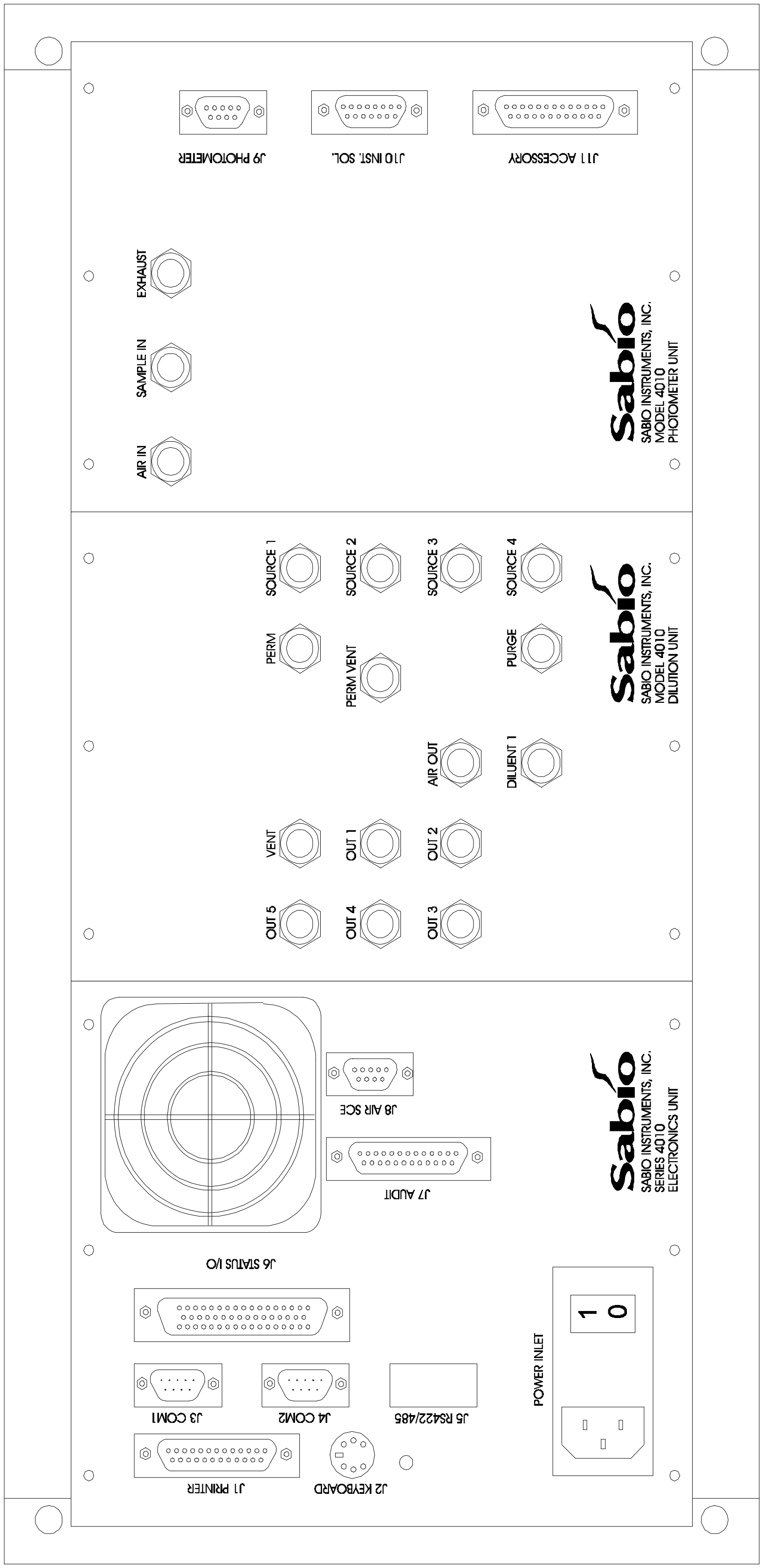


Figure 4-1 Rear Panel

Source gases are connected to Source Gas Input Ports, 1 through 4 and optionally Source Gas Input Ports 5 and 6. **Source gas pressures must be regulated to 20 - 25 psig to prevent damage to the Model 4010.** Cap all unused Source Gas Input Ports.

An optional Sabio Instruments Model 4010 or Model 2500 Permeation Oven may be connected to the optional Perm Tube Input Port.

The Purge port should be connected to the system exhaust manifold. Instrument exhaust ports should also be connected to the system exhaust manifold.

On all versions of the Model 4010 calibrators, zero gas is available through the Span Gas Out ports when a zero point is produced.

The Vent Output Port should be connected to the system exhaust manifold. Instrument Span Gas Input ports are connected to the remaining Span Gas Out Ports, 1 through 7 starting with port 1. **Cap all Span Gas Out ports that do not have connections.**

Power

The standard operating voltage for the Model 4010 calibrators is 96 - 264 VAC at a frequency of 50/60 Hz. The power consumption for the Model 4010 is approximately 150 - 300 VA. Ensure that the power source is rated properly. An adequate earth ground must be available through the AC power plug to ensure safe operation of the unit and to prevent electrical shock hazard.

Parallel Printer Data Port

A standard, off-the-shelf, parallel port printer data cable with a DB-25 connector on the Model 4010 printer port end and a Centronics port connector on the other end will generally work for connections between the Model 4010 and the printer in most instances.

The Parallel Printer connector J1 on the rear panel of the Model 4010 is a female type DB-25 connector.

Table 4-2 Parallel Printer Port Connections

4010 J1	SIGNAL SIGNATURE
J1-1	STROBE
J1-2	DATA BIT 1
J1-3	DATA BIT 2
J1-4	DATA BIT 3
J1-5	DATA BIT 4
J1-6	DATA BIT 5
J1-7	DATA BIT 6
J1-8	DATA BIT 7
J1-9	DATA BIT 8
J1-10	ACKNOWLEDGE
J1-11	BUSY
J1-12	PAPER OUT
J1-13	SELECT
J1-14	AUTO FEED ERROR
J1-15	ERROR
J1-16	INITIALIZE PRINTER
J1-17	SELECT INPUT
J1-18	DIGITAL GROUND
J1-19	DIGITAL GROUND
J1-20	DIGITAL GROUND
J1-21	DIGITAL GROUND
J1-22	DIGITAL GROUND
J1-23	DIGITAL GROUND
J1-24	DIGITAL GROUND
J1-25	DIGITAL GROUND

Keyboard Port

A standard, off-the-shelf, PCAT type keyboard may be connected to J2. A 6 pin circular mini-din female connector is provided on the rear panel of the Model 4010 for this purpose.

Table 4-3 External Keyboard Port Connections

4010 J2	SIGNAL SIGNATURE
J2-1	KEY DATA
J2-2	NO CONNECTION
J2-3	DIGITAL GROUND
J2-4	+5 VOLTS
J2-5	CLOCK
J2-6	NO CONNECTION

RS-232 Serial Communications Port 1

The cable should be equipped with a 9 pin female D connector on one end and an appropriate connector on the other end.

The COM1 connector J3 on the rear panel of the Model 4010 is a male type DB-9 connector.

Table 4-4 Communications Port 1 Connections

4010 J3	SIGNAL SIGNATURE
J3-1	DATA CARRIER DETECT
J3-2	RECEIVE DATA
J3-3	TRANSMIT DATA
J3-4	DATA TERMINAL READY
J3-5	DIGITAL COMMON
J3-6	DATA SET READY
J3-7	REQUEST TO SEND
J3-8	CLEAR TO SEND
J3-9	RING INDICATOR

RS-232 Serial Communications Port 2

The cable should be equipped with a 9 pin female D connector on one end and an appropriate connector on the other end.

The COM2 connector J4 on the rear panel of the Model 4010 is a male type DB-9 connector.

Table 4-5 Communications Port 2 Connections

4010 J4	SIGNAL SIGNATURE
J4-1	DATA CARRIER DETECT
J4-2	RECEIVE DATA
J4-3	TRANSMIT DATA
J4-4	DATA TERMINAL READY
J4-5	DIGITAL COMMON
J4-6	DATA SET READY
J4-7	REQUEST TO SEND
J4-8	CLEAR TO SEND
J4-9	RING INDICATOR

RS-232 Serial Communications Cable, Model 4010 to PC

A null modem cable is required when connecting the Model 4010 to a personal computer for downloading software updates, remote control or other applications. The cable should be equipped with a 9 pin female D connector on the Model 4010 serial communication port end for COM1 or COM2 and a 9 pin female D connector or 25 pin female D connector on the PC end. The pin outs for the null modem cable are given in Table 4-6. Note that the Pin 1 (CD) and Pin 6 (DSR) are tied together on each end of the cable since some terminal programs require the CD line to be pulled high.

Table 4-6 Model 4010 to PC Connections

SIGNAL SIGNATURE		4010 9 PIN FEMALE	SIGNAL FLOW	PC 9 PIN FEMALE	PC 25 PIN FEMALE
CARRIER DETECT	CD	1	<---------	4	20
RECEIVE DATA	RXD	2	<---------	3	2
TRANSMIT DATA	TXD	3	---------->	2	3
DATA TERMINAL READY	DTR	4	---------->	6,1	6,8
DIGITAL COMMON	GND	5	-----------	5	7
DATA SET READY	DSR	6	<----------	4	20
REQUEST TO SEND	RTS	7	---------->	8	5
CLEAR TO SEND	CTS	8	<----------	7	4
RING INDICATOR	RI	9			

RS-232 Serial Communications Cable, Model 4010 to Modem

A modem cable is required when connecting the Model 4010 to a modem for downloading software updates, remote control or other applications. The cable should be equipped with a 9 pin female D connector on the Model 4010 serial communication port end for COM1 or COM2 and a 9 pin female D connector or 25 pin female D connector on the PC end. The pin outs for the modem cable are given in Table 4-7.

Table 4-7 Model 4010 to Modem Connections

4010 9 PIN SIGNAL SIGNATURE		SIGNAL FEMALE	Modem 25 PIN FLOW	MALE
CARRIER DETECT	CD	1	<---------	8
RECEIVE DATA	RXD	2	<---------	3
TRANSMIT DATA	TXD	3	---------->	2
DATA TERMINAL READY	DTR	4	---------->	20
DIGITAL COMMON	GND	5	-----------	7
DATA SET READY	DSR	6	<----------	6
REQUEST TO SEND	RTS	7	---------->	4
CLEAR TO SEND	CTS	8	<----------	5
RING INDICATOR	RI	9	<----------	22

Status Input/Output Port

The Model 4010 Calibrators are equipped with 24 digital Input/Output bits which may be programmed to control calibration sequences and provide status output information on the calibration process.

Relay contact closures or TTL logic connected to the appropriate bit(s) and corresponding common(s), are used to activate programmed calibration sequences. The active state is with the contact closed or a logic level of 0 for TTL logic. The TTL device must be capable of sinking 1 ma of current (5 mw of power) per bit. All unused leads should be covered with insulation.

Status output ports can be used to interface with Opto-22 devices. The signal levels are TTL voltages. The current into the pulled-up open collector transistor outputs should not exceed 20 ma. The bits are low in their active state. For example if Instrument 1 bit were activated, the collector would be pulled low.

--- CAUTION ---

> Under no circumstances should the current into each control output bit be allowed to exceed 20 ma.

The signatures and connections are shown in Table 4-8, below. See Figure 4-1 for pictorial drawing of the rear panel.

The Status Input/Output connector J6 on the rear panel of the Model 4010 is a female type DB-50 connector.

Table 4-8 Status Input / Output Port Connections

4010 J6	SIGNAL SIGNATURE
J6-1	STATUS I/O BIT 1
J6-2	DIGITAL GROUND
J6-3	STATUS I/O BIT 2
J6-4	DIGITAL GROUND
J6-5	STATUS I/O BIT 3
J6-6	DIGITAL GROUND
J6-7	STATUS I/O BIT 4
J6-8	DIGITAL GROUND
J6-9	STATUS I/O BIT 5
J6-10	DIGITAL GROUND
J6-11	STATUS I/O BIT 6

Table 4-8 Status Input / Output Port Connections (Continued)

4010 J6	SIGNAL SIGNATURE
J6-12	DIGITAL GROUND
J6-13	STATUS I/O BIT 7
J6-14	DIGITAL GROUND
J6-15	STATUS I/O BIT 8
J6-16	DIGITAL GROUND
J6-17	STATUS I/O BIT 9
J6-18	DIGITAL GROUND
J6-19	STATUS I/O BIT 10
J6-20	DIGITAL GROUND
J6-21	STATUS I/O BIT 11
J6-22	DIGITAL GROUND
J6-23	STATUS I/O BIT 12
J6-24	DIGITAL GROUND
J6-25	STATUS I/O BIT 13
J6-26	DIGITAL GROUND
J6-27	STATUS I/O BIT 14
J6-28	DIGITAL GROUND
J6-29	STATUS I/O BIT 15
J6-30	DIGITAL GROUND
J6-31	STATUS I/O BIT 16
J6-32	DIGITAL GROUND
J6-33	STATUS I/O BIT 17

J6-34	DIGITAL GROUND
J6-35	STATUS I/O BIT 18
J6-36	DIGITAL GROUND
J6-37	STATUS I/O BIT 19
J6-38	DIGITAL GROUND
J6-39	STATUS I/O BIT 20
J6-40	DIGITAL GROUND
J6-41	STATUS I/O BIT 21
J6-42	DIGITAL GROUND
J6-43	STATUS I/O BIT 22
J6-44	DIGITAL GROUND
J6-45	STATUS I/O BIT 23
J6-46	DIGITAL GROUND
J6-47	STATUS I/O BIT 24
J6-48	DIGITAL GROUND
J6-49	NO CONNECTION
J6-50	DIGITAL GROUND

Instrument Audit Analog Input/Output Port

A standard, off-the-shelf, serial data cable with a 25 pin D male connector and clip on leads is supplied as part of the instrument audit option. A custom cable may be required to meet specific customer needs. The cable should be equipped with a 25 pin male D connector on one end and appropriate connections on the other end.

Care should be taken to avoid ground loops and to prevent damage to sensitive analog input circuitry. Analog input signals should be a maximum of 10 Volts DC or less.

Table 4-9 Audit Port Connections

4010 J7	SIGNAL SIGNATURE
J7-1	CHASSIS GROUND
J7-14	CHASSIS GROUND
J7-2	DAS 1 OUTPUT
J7-15	ANALOG GROUND
J7-3	DAS 2 OUTPUT
J7-16	ANALOG GROUND
J7-4	DAS 3 OUTPUT
J7-17	ANALOG GROUND
J7-5	DAS 4 OUTPUT
J7-18	ANALOG GROUND
J7-6	AIN 1 INPUT +
J7-19	AIN 1 INPUT -
J7-7	AIN 2 INPUT +
J7-20	AIN 2 INPUT -
J7-8	AIN 3 INPUT +
J7-21	AIN 3 INPUT -
J7-9	AIN 4 INPUT +
J7-22	AIN 4 INPUT -
J7-10	ANALOG GROUND
J7-23	ANALOG GROUND

Air Source Activation Port

A standard, off-the-shelf, serial data cable with all pins wired one to one on both ends will work for connections between the Model 4010 and the Sabio Engineering Model 1001 Compressed Air Source. A custom cable may need to be fabricated for other Compressed Air Sources. The cable for activating a Model 1001 should be equipped with a 9 pin male D connector for the Model 4010 end and a 9 pin female D connector for the Model 1001 end.

The output module which activates the air source is configured at the factory to provide switched 12 volts DC. When using an alternate compressed air source, current draw should be limited to 200 ma. Inductive loads such as solenoids and relays must have snubber diodes in parallel with their coils. The diode anode should be connected to J8-6.

The Air Source Control connector J8 on the rear panel of the Model 4010 is a female type DB-9 connector.

Table 4-10 Air Source Activation Port Connections

4010 J8	SIGNAL SIGNATURE
J8-1	CHASSIS GROUND
J8-2	AIR ON HIGH (Switched DC)
J8-6	AIR ON LOW (Analog Ground)

Photometer Analog Output Connections

If the Photometer option is installed and the Photometer's output is to be monitored by a strip chart recorder, datalogger or other external device, a cable must be made with the connections listed in the Table, below.

Table 4-11 Photometer Analog Output Connections

4010 J9	SIGNAL SIGNATURE
J9-1	CHASSIS GROUND
J9-2	DAS OUT 1
J9-3	DAS OUT 2
J9-4	DAS OUT 3
J9-5	RESERVED
J9-6	CHASSIS GROUND
J9-7	GROUND
J9-8	GROUND
J9-9	GROUND

In addition to the physical wiring connections, the analog output parameters must be set up for the specific application. The 4010 allows the scaling and averaging of each analog output to be independently set from the Photometer Parameters screen, as described beginning on Page 9-12.

Instrument Solenoid Connections

If the Instrument Solenoid option is installed, external solenoid valves may be attached to connector J10 and automatically activated when an associated calibration Sequence or Point is active. J10 is located on the option module's rear panel (see Figure 4-1), which may also support other connectors related to the Photometer or Permeation Oven, depending upon what options are installed.

Table 4-12 Instrument Solenoid Connections

4010 J10	SIGNAL SIGNATURE
J10-1	CHASSIS GROUND
J10-2	INSTRUMENT SOLENOID 1
J10-3	INSTRUMENT SOLENOID 2
J10-4	INSTRUMENT SOLENOID 3
J10-5	INSTRUMENT SOLENOID 4
J10-6	INSTRUMENT SOLENOID 5
J10-7	INSTRUMENT SOLENOID 6
J10-8	
J10-9	CHASSIS GROUND
J10-10	GROUND
J10-11	GROUND
J10-12	GROUND
J10-13	GROUND
J10-14	GROUND
J10-15	GROUND

Each Instrument Solenoid output provides 24 Volts when active and is capable of directly driving an external 24 Volt Solenoid Valve. Although each output can power solenoid valves requiring up to 9 Watts of power, only a total of 9 Watts may be supplied from the 4010's power supply at any one time. Ordinarily, since only one or two Instrument Solenoids will be active at a time, this is sufficient.

--- CAUTION ---

> Under no circumstances should the total current drawn from all Instrument Solenoids exceed 375mA (9 Watts at 24 Volts) at any one time.

Which Instrument Solenoid is to be activated for a given calibration Sequence or Point is determined by the Sequence Setup screen, which is described in more detail in the section "Defining Calibration Sequences", starting on Page 6-8.

External Permeation Oven Connections

If the External Permeation Oven is installed, it is connected via a cable attached to J11. J11 is located on the option module's rear panel (see Figure 4-1), which may also support other connectors related to the Photometer or Instrument Solenoid options.

Table 4-13 External Permeation Oven Connections

4010 J11	SIGNAL SIGNATURE
J10-1	
J10-2	
J10-3	
J10-4	
J10-5	
J10-6	
J10-7	
J10-8	
J10-9	
J10-10	
J10-11	
J10-12	
J10-13	
J10-14	
J10-15	
J10-16	
J10-17	
J10-18	
J10-19	
J10-20	
J10-21	
J10-22	
J10-23	
J10-24	
J10-25	

Section 5 Operation

This section introduces the customer to the use and day-to-day operation of the Model 4010. The operations described here assume that the 4010 has already been configured for a specific application as described in Section 6.

Performing Automatic Calibrations

Upon power-up, the Model 4010 is placed in a "Standby" mode, waiting for time to perform automatic scheduled calibrations or to initiate calibration sequences or points in response to remote control commands. The 4010 is always ready to initiate automatic scheduled calibrations unless manual calibrations are being performed. When performing manual calibrations, automatically scheduled calibrations will not take place, but will be postponed until the next scheduled time.

Calibration Sequences and Diluent and Source Gases must be defined before performing automatic calibrations. Refer to Section 6, "Model 4010 Calibration Set-up", for more information.

Automatic calibrations can either be activated externally by a device such as a data acquisition system or internally by the Model 4010's clock. The Model 4010 has 24 digital I/O bits that can be activated externally to initiate auto calibration sequences. Depending upon how the I/O bits are assigned, the external device can either step the 4010 through each calibration point contained in the calibration sequence or initiate a calibration sequence, allowing the 4010's timer to step through each calibration point.

Automatically timed sequences are set up as described in the subsection "Scheduling Automatic Calibrations" in Section 6. Externally activated sequences and sequence points are assigned to digital I/O bits as described in the topics "Assigning Sequence Start Patterns" and "Assigning Point Start Patterns", in Section 6. Wiring is covered in the subsection titled "Status Input/Output Port" Section 4.

Calibrating Multiple Analyzers in One Calibration Session

When using gas blends for auto calibration of multiple analyzers, the Model 4010 has the capability to calculate span concentrations for each gas in the blend. For example, three instruments may be calibrated simultaneously with a gas blend containing SO_2, NO, and CO. One of these gases must be assigned as the "primary gas" when the sequence is set up; the other two will be considered secondary gases. The 4010 will automatically calculate the concentrations of all gases in a multi-blend gas standard and present them in the status screen. The concentrations assigned to the primary gas for each sequence point will determine the concentrations of the secondary gases, which are calculated from the dilution ratio needed to produce the primary gas and the relative concentrations of the secondary gases in the gas standard.

Performing Manual Calibrations

The Model 4010 may be used to perform instrument calibrations manually by accessing the programmed calibration sequences. The programmed sequences are found under the main menu area identified as Sequences. The Run item in the Sequences menu allows manual calibrations to be invoked by two methods: Operator Stepped and Timer Stepped.

Calibration sequences and Diluent and Source Gases must be defined before performing manual calibrations. Refer to Section 6, "Model 4010 Calibration Set-up", for more information.

Each method of performing manual calibrations is described in the subsections that follow.

Predefined Operator Stepped Manual Calibration

To perform a manual calibration using predefined or programmed sequences, perform the following steps:

[1] From the Main Menu screen, select Sequences and press the Enter button. A pop-up menu will appear.

[2] Select Run, and press the Enter button. Another pop-up menu will appear that allows the choice of which type of manual calibration you wish to use.

[3] Select Operator Stepped from the menu and press the Enter button. A list of sequences that have been predefined or programmed will appear (see Figure 5-1).

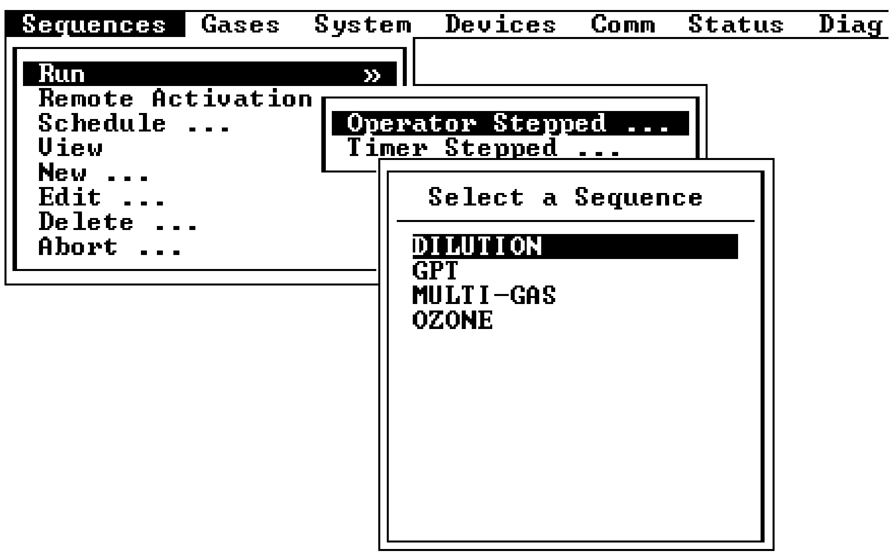


Figure 5-1 Manual Sequence Selection Menu

[4] Select the sequence containing the point you want to run. The "Select a Point to Run" screen shown in Figure 5-2 will appear, displaying the Sequence Name and Type, the Primary Gas Name and concentrations for each point in the sequence and a box entitled "Run Point Number", which will allow the user to select a calibration point to run.

```
                        Select a Point to Run
Sequence Name : DILUTION
Sequence Type : Gas Dilution                      Run Point Number: 2

                      Concentration                               Concentration
                     Primary   Ozone                             Primary   Ozone
Point  Gas Name       (PPB)    (PPB)     Point  Gas Name          (PPB)    (PPB)

  1    SO2             100                11    SO2                 0
  2    SO2             200                12    SO2                50
  3    SO2             300
  4    SO2             400
  5    SO2             500
  6    SO2             600
  7    SO2             700
  8    SO2             800
  9    SO2             900
 10    SO2            1000
```

Figure 5-2 The "Select a Point to Run" Screen

[5] Select a calibration point to run by entering a number corresponding to the desired calibration point and then press the Enter button. The selected sequence point will be started and a status screen will appear (see Figure 5-3). The type of the status screen that appears will depend upon which type of sequence is started. Near the bottom of the screen, on the status line, the name of the sequence and the active point number will be displayed.

```
 Sequences  Gases  System  Devices  Comm  Status  Diag
                      Dilution Calibration Status
 (*) Engineering Units   ( ) Voltage Units
                                                  Diluent: AIR
 ------ Dilution Flow Controllers -------        Source : CAL STANDARD
                     Control      Monitor
                                                  ------- Diluted Gases -------
 Diluent MFC   :     4.886      4.886 SLPM                SO2:      200 PPB
 Ozone MFC ... :     100.0       99.8 SCCM                 CO:     2860 PPB
 Source 1 MFC  :      14.3       14.3 SCCM
 Total Flow .. :     5.000      5.000 SLPM

 ------ Dilution Solenoids -------
 Diluent    Source       Instrument

 1[X]     1[X]  4[ ]    1[ ]  4[ ]
 2[ ]     2[ ]  5[ ]    2[ ]  5[ ]
          3[ ]  6[ ]    3[ ]  6[ ]

 Output [X]  Purge [ ]
 Tue 01/06/98 11:01:42  Seq: DILUTION         Point: 2               OVR
             F2=PREV    F3=NEXT    F4=PAGE UP F5=PAGE DN F6=VOLTS    F7=UNITS
```

Figure 5-3 The Sequence Status Screen

[6] Allow an appropriate amount of time for the analyzer to stabilize before recording concentrations. When ready for the next point, press the End Sequence button to exit the status screen and return to the "Select a Point to Run" screen. Select another calibration point by entering the point number and pressing the Enter button. Repeat this process for each calibration point.

[7] To end the calibration session, press the End Sequence button until a box appears with Yes or No to abort the active sequence. Select Yes and press the Enter button to abort the sequence. Select No and press the Enter button if you wish to keep the sequence active.

Timer Stepped Manual Calibration

Starting a Timer Stepped manual calibration is very similar to starting an Operator Stepped manual calibration, except that a calibration point is not selected and the 4010 automatically steps the sequence through each point based on the point's duration. To perform a Timer Stepped manual calibration, the following steps are performed:

[1] From the Main Menu screen, select Sequences and press the Enter button. A pop-up menu will appear.

[2] Select Run, and press the Enter button. Select Timer Stepped from the menu and press the Enter button. A list of the defined sequences will appear.

[3] Select the sequence you wish to run and press the Enter button. The first point of the selected sequence point will be started and a status screen relevant for the selected sequence type will appear as shown in Figure 5-3. The status line near the bottom of the screen will indicate which sequence and point is active.

[4] At this time the 4010's timer will be in control of the calibration process and will step through each calibration point in the sequence. The 4010 will hold each point for the duration that was entered when the sequence was set up.

[5] To end the calibration session, press the End Sequence button until a box appears with Yes or No to abort the active sequence. Select Yes and press the Enter button to abort the sequence. Select No and press the Enter button if you wish to keep the sequence active.

Viewing Calibration Status

Pressing the Status button (or the F8 key on an external keyboard) or selecting "Status" from the main menu will cause a status screen to be displayed. The status screen is also displayed automatically when a manual calibration is started. The status screen presents information about the calibration in progress, such as the control and monitor values of the flow controllers, temperature controllers and ozone generator, the states of the solenoid valves and calculated values such as total flow and diluted gas concentrations.

There are four main status screens: Idle, Dilution, Ozone and GPT (see Figure 5-4, Figure 5-5, Figure 5-6, and Figure 5-7). If the Permeation Oven or Photometer options are installed, status screens for these devices will also be available. The type of status screen that is displayed depends upon the type of sequence that is currently active.

At the top of each status screen are selection buttons which allow the status information to be presented in either engineering units or voltage units. To select a different display mode, press one of the arrow buttons and then press Enter to select. An easier method is to simply press the F6 key to toggle between engineering and voltage units.

Following are examples of the main types of status screens:

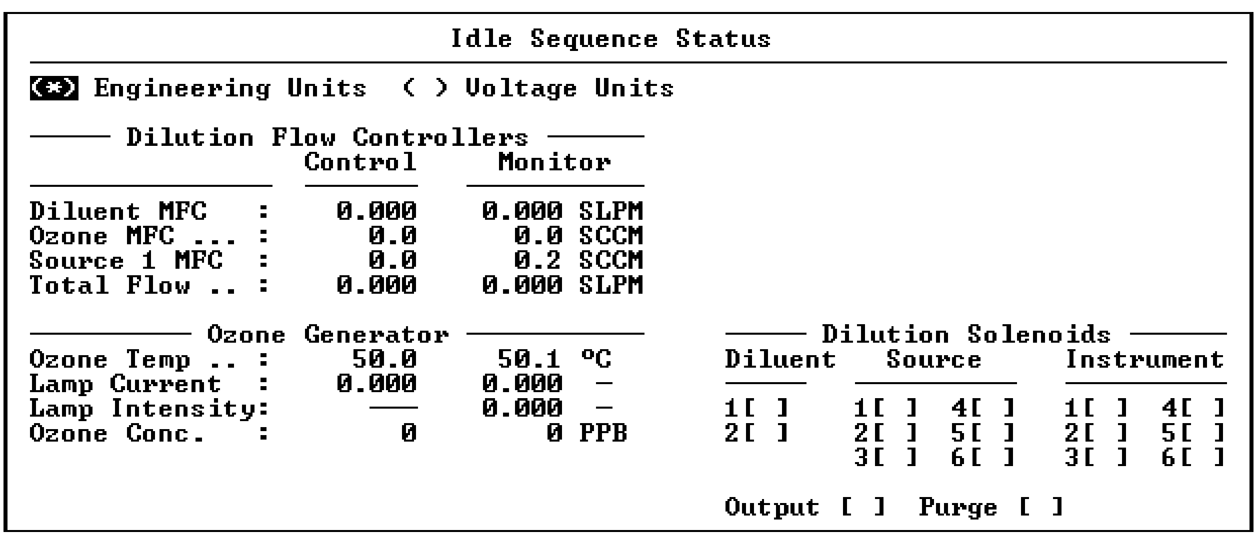


Figure 5-4 The Idle Status Screen

```
                         Dilution Calibration Status
(*) Engineering Units  ( ) Voltage Units
                                              Diluent: AIR
---- Dilution Flow Controllers ----           Source : CAL STANDARD
                 Control     Monitor
                                              ------ Diluted Gases ------
Diluent MFC   :   4.886    4.886 SLPM                 SO2:     200 PPB
Ozone MFC ... :   100.0     99.8 SCCM                  CO:    2860 PPB
Source 1 MFC  :    14.3     14.3 SCCM
Total Flow .. :   5.000    5.000 SLPM

---- Dilution Solenoids ----
Diluent   Source     Instrument

1[X]     1[X]  4[ ]  1[ ]  4[ ]
2[ ]     2[ ]  5[ ]  2[ ]  5[ ]
         3[ ]  6[ ]  3[ ]  6[ ]

Output [X]  Purge [ ]
```

Figure 5-5 The Dilution Status Screen

```
                         Ozone Calibration Status
(*) Engineering Units  ( ) Voltage Units

---------- Ozone Generator ----------   ---- Dilution Solenoids ----
                 Control     Monitor    Diluent   Source      Instrument

Diluent Flow  :   4.900    4.900 SLPM   1[X]     1[ ]  4[ ]  1[ ]  4[ ]
Ozone Flow .. :   100.0    100.1 SCCM   2[ ]     2[ ]  5[ ]  2[ ]  5[ ]
Ozone Temp .. :    50.0     50.1 ºC              3[ ]  6[ ]  3[ ]  6[ ]
Lamp Current  :   1.548    1.548  -
Lamp Intensity:     ---    1.547  -     Output [X]  Purge [ ]
Ozone Conc.   :     400      400 PPB
```

Figure 5-6 The Ozone Status Screen

```
                         GPT Calibration Status
(*) Engineering Units   ( ) Voltage Units
                                                  Diluent: AIR
------ Dilution Flow Controllers -------          Source : NO STANDARD
                      Control    Monitor
                                                  --- Projected GPT Results ---
Diluent MFC   :      4.864     4.865 SLPM                 NOX:     500 PPB
Ozone MFC ... :      100.0     100.0 SCCM                  NO:     100 PPB
Source 1 MFC  :       35.7      35.7 SCCM                 NO2:     400 PPB
Total Flow .. :      5.000     5.001 SLPM                  O3:       0 PPB

----------- Ozone Generator ------------          ----- Dilution Solenoids ------
Ozone Temp .. :       50.0      50.1 °C         Diluent   Source     Instrument
Lamp Current  :      1.548     1.548  -
Lamp Intensity:        ---     1.547  -         1[X]     1[ ] 4[ ]   1[ ] 4[ ]
Ozone Conc.   :        400       400 PPB        2[ ]     2[ ] 5[ ]   2[ ] 5[ ]
                                                         3[X] 6[ ]   3[ ] 6[ ]

                                                Output [X]  Purge [ ]
```

Figure 5-7 The GPT Status Screen

Performing Manual Calibrations using the Status Screen

Normally, when a status screen is displayed, the only item that can be changed is the engineering or voltage units selector button, however by entering debug mode, any of the control values or solenoid valves may be changed. This is a very useful feature, allowing devices to be tested individually or manual calibrations to be performed. Debug mode is toggled on or off by pressing the "Diag." Button on the front panel or F11 on an external keyboard while the status screen is displayed.

Before performing calibrations using debug mode, it is important that the user has a good understanding of the pneumatic operation of the 4010 and the purposes of it's various flow controllers and solenoid valves. In this mode, it is entirely up to the user to manually activate the appropriate solenoid valves, flows rates, ozone generator, etc. for the desired result. It is also up to the user to calculate the flow rates needed for the desired gas concentrations.

In the following example, a GPT calibration will be activated manually using the status screen in debug mode. In the example, a concentration of 400 PPB of ozone will be mixed with 500 PPB of NO at a total flow rate of 5.000 SLPM, resulting in 500 PPB of NOx, 400 PPB of NO2 and 100 PPB of excess NO. The source cylinder, attached to source inlet 1, contains 50,000 PPB of NO. The following steps are required to perform this calibration using the status screen.

[1] Calculate the source and diluent flow rates as follows:

If:

```
Desired Concentration = 500 PPB
Source Concentration  = 50,000 PPB
Total Flow            = 5.000 SLPM (5000 SCCM)
Ozone Flow            = 100 SCCM
```

Then:

```
                Desired Concentration X Total Flow
Source Flow  =  ----------------------------------
                      Source Concentration

                500 X 5000
             =  ---------- = 50 SCCM
                 50,000

Diluent Flow =  Total Flow - Ozone Flow - Source Flow

             =  5000 - 100 - 50 = 4850 SCCM = 4.850 SLPM
```

[2] From the Main Menu screen, select Status and press the Enter button then select Current Status and press enter. Assuming no calibrations are active, the Idle Sequence Status screen will appear as shown in Figure 5-4.

[3] Press the "Diag." button (or F11 on an external keyboard) until the message "Debug Mode" is presented on the status line near the bottom of the screen.

[4] Press the F3 (Tab) key until the Diluent MFC Control value is highlighted. Enter the calculated diluent flow rate (e.g. 4.850 SLPM) and press Enter or F3. Notice that an "X" appears in the box associated with the Diluent 1 solenoid valve indicating that it has been automatically activated. Also note that, assuming a pressurized diluent source is attached, the monitor value will increase until it approximately matches the control value.

[5] The Ozone MFC Control field should now be highlighted. Enter 100 SCCM and press Enter or F3. The Ozone MFC Monitor value should increase until it approximately matches the control value.

[6] The Source 1 MFC Control should now be highlighted. Enter the calculated source flow value (e.g. 50 SCCM). Though the Source 1 MFC has been activated, no monitor flow will be indicated until a source solenoid valve has been activated.

[7] Press the F3 key, skipping the Ozone Temp field until the Lamp Current field is highlighted. This is a value between 0 and 5 corresponding to the current applied to the ozone generator's lamp. Enter a value, for example 1.000, and observe the calculated "Ozone Conc." control value. This will indicate the ozone concentration that should be produced based on the lamp current, the last ozone generator calibration and the total flow rate.

Adjust the lamp current experimentally until the desired ozone concentration is reached (e.g. 400 PPB). This is done by backing up with the F2 (Shift-Tab) key and entering different Lamp Current values until the calculated ozone is showing the desired concentration.

[8] Press F3 until the source solenoid valve associated with the gas cylinder containing Nitric Oxide (NO) is selected. Press "1" or Space so that an "X" appears in the box. If a pressurized gas source is attached, the Source 1 MFC Monitor flow should now increase until it has approximately matched the control value. A gas concentration determined by the diluent and source flow rates, the source gas concentration and the Ozone Generator Lamp Current will now be produced by the 4010.

[9] To change concentrations or select a different gas, use the F2 and F3 buttons (Shift-Tab and Tab) to move the cursor to the appropriate field and then change the value.

[10] To stop the calibration, press the End Sequence button until a box appears with Yes or No to abort the active sequence. Select Yes and press the Enter button to stop everything and return to a quiescent state.

Viewing Diagnostic Information

Occasionally, it is necessary to directly view the 4010's analog or digital inputs or outputs. The "Diag" (Diagnostics) menu is provided for this purpose. There are four entries under the Diag menu: Analog Inputs, Analog Outputs, Control Outputs and Monitor I/O Bits. These diagnostic screens, which present the data in real time, updated each second, are described in more detail below.

The Analog Input Screen

The Analog Input screen shown in Figure 5-8 allows each of the 24 analog inputs to be viewed in either engineering or voltage units. All available inputs are shown in this screen even though some are only applicable when the corresponding options (e.g. Photometer or Perm Oven) are installed. Inputs associated with uninstalled options are usually floating and their values are meaningless. The last four channels (25 - 28) are internal voltage reference and zero channels that are used for automatic zero/span correction.

The data presented in the screen can be viewed in either engineering or voltage units by selecting the appropriate button on the screen and pressing enter (or by toggling the selection with the F6 key). If the "Diag." Button is pressed while this screen is displayed, a special debug mode is entered that allows the A/D scanning to be halted and a particular analog input channel to be frozen. This function is normally not needed by the user and is intended for factory use.

Analog Inputs

(*) Engineering Units ( ) Voltage Units

Channel	Voltage	Function	Channel	Voltage	Function
1	0.0 SCCM	Source 2 MFC	15	0.0 SCCM	Perm Oven Flow
2	0.1 SCCM	Source 1 MFC	16	0.0 °C	Ext. Perm Temp
3	0.1 SCCM	Ozone Flow	17	0.909 V	Spare AIN 2
4	0.000 SLPM	Diluent MFC	18	1.011 V	Spare AIN 3
5	50.4 °C	Ozone Temp	19	0.0 °C	Photo Lamp Temp
6	0.000 V	O3 Lamp Current	20	0.003 V	Photo Lamp Curr
7	0.000 V	O3 Lamp Int	21	3.955 V	Photo Lamp Int
8	27.2 °C	Instrument Temp	22	41.5 °C	Photo Samp Temp
9	647 mmHg	Instrument Pres	23	724 mmHg	Photo Samp Pres
10	0.949 V	Spare AIN 1	24	155 SCCM	Photo Samp Flow
11	1.472 V	Audit 1 Input	25	1.584 V	Ref 5 V
12	1.472 V	Audit 2 Input	26	151.8 mV	Ref 0.4955 V
13	1.483 V	Audit 3 Input	27	11.6439 mV	Ref 45.05 mV
14	1.421 V	Audit 4 Input	28	-0.004 V	Ref 0 V

Figure 5-8 The Analog Input Diagnostic Screen

The Analog Ouput Screen

The Analog Output screen, shown in Figure 5-9, not only allows each of the 20 analog outputs to be viewed, but also allows the current settings to be changed. As with the Analog Input Screen, the values can be displayed in either engineering or voltage units. In addition, the units of measure may be changed for each output by pressing the F7 key. In some cases, other outputs with the same units will also be changed to the new units. For example, positioning the cursor over the Ozone Temp field by using the F2 and F3 keys and pressing F7 will cause all temperatures to be presented in units of °F; even within in other screens.

Analog Outputs

(*) Engineering Units ( ) Voltage Units

Channel	Voltage	Function	Channel	Voltage	Function
1	5.000 V	Disp Intensity	11	0.000 V	DAS 4 Output
2	0.2 SCCM	Source 2 MFC	12	0.0 SCCM	Perm Oven Flow
3	0.0000 SLPM	Source 1 MFC	13	32.0 °F	Ext. Perm Temp
4	0.0 SCCM	Ozone Flow	14	0.000 V	Spare AOUT 1
5	0.002 SLPM	Diluent MFC	15	0.000 V	Spare AOUT 2
6	122.4 °F	Ozone Temp	16	32.0 °F	Photo Lamp Temp
7	0.000 V	O3 Lamp Current	17	0.000 V	Photo Lamp Curr
8	0.000 V	DAS 1 Output	18	0 PPB	Photo DAS 1 Out
9	0.000 V	DAS 2 Output	19	0 PPB	Photo DAS 2 Out
10	0.000 V	DAS 3 Output	20	0 PPB	Photo DAS 3 Out

Figure 5-9 The Analog Ouput Diagnostic Screen

The Internal Control Outputs and User Digital I/O Bits Screens

The Internal Control Outputs, shown in Figure 5-10, displays the current states of all 24 of the Internal Control Outputs that are used for driving internal solenoid valves and other on-off devices. A similar screen, the User Digital I/O Bits screen shown in Figure 5-11, displays the states of the 24 User Digital I/O Bits that may be used for remote control and sensing of sequences.

For both screens, each bit may serve as either an input or an output. If an output control is inactive, the bit will sense changes in the I/O line. If an output is active, the associated input bit will sense the active state as if it were activated externally. The Internal Control Output bits are only used as outputs, however the input bit sensing can be a useful diagnostic, indicating that the bit was physically activated.

```
                         Internal Control Outputs

Bit   State   Function               Bit   State   Function

 1     [ ]    Display                13     [ ]    Photo Pump Sol
 2     [X]    Diluent 1              14     [ ]    Photo Ref Sol
 3     [ ]    Diluent 2              15     [ ]    Photo Samp Sol
 4     [X]    Source 1               16     [ ]    Perm Vent
 5     [ ]    Source 2               17     [ ]    Perm Source
 6     [ ]    Source 3               18     [ ]    Perm Pump
 7     [ ]    Source 4               19     [ ]    Instrument 1
 8     [ ]    Source 5               20     [ ]    Instrument 2
 9     [ ]    Source 6               21     [ ]    Instrument 3
10     [ ]    Purge                  22     [ ]    Instrument 4
11     [X]    Output Solenoid        23     [ ]    Instrument 5
12     [ ]    Ext Perm Source        24     [ ]    Instrument 6

X or 1 = On (contact or low) Bit: 1      8 9     16 17    24
     0 = Off(open or high)   Out: 01010000 00100000 00000000
                             In : 01010000 00100000 00000000
```

Figure 5-10 The Internal Control Ouputs Diagnostic Screen

```
                           User Digital I/O Bits

Bit   State   Function               Bit   State   Function

 1     [ ]    I/O Bit 1              13     [ ]    I/O Bit 13
 2     [ ]    I/O Bit 2              14     [ ]    I/O Bit 14
 3     [ ]    I/O Bit 3              15     [ ]    I/O Bit 15
 4     [ ]    I/O Bit 4              16     [ ]    I/O Bit 16
 5     [ ]    I/O Bit 5              17     [ ]    I/O Bit 17
 6     [ ]    I/O Bit 6              18     [ ]    I/O Bit 18
 7     [ ]    I/O Bit 7              19     [ ]    I/O Bit 19
 8     [ ]    I/O Bit 8              20     [ ]    I/O Bit 20
 9     [ ]    I/O Bit 9              21     [ ]    I/O Bit 21
10     [ ]    I/O Bit 10             22     [ ]    I/O Bit 22
11     [ ]    I/O Bit 11             23     [ ]    I/O Bit 23
12     [ ]    I/O Bit 12             24     [ ]    I/O Bit 24

X or 1 = On (contact or low) Bit: 1      8 9     16 17    24
     0 = Off(open or high)   Out: 00000000 00000000 00000000
                             In : 00000000 00000000 00000000
```

Figure 5-11 The User Digital I/O Bits Diagnostic Screen

Both screens operate in the same way. An "X" in the square brackets that are associated with each input or output bit indicates that that I/O bit is active; either because the 4010 has activated it or because it has been activated externally. In the bottom right corner, the 24 I/O bits are presented as two groups of 1's and 0's, where "1" corresponds to the active state. The group labeled "Out" represents the control states, while the "In" group represent the status inputs that are read back. The two groups allow the user to determine if a bit is active due to internal or external control.

When an output is activated, the bit in the "Out" group will indicate "1" immediately, but the corresponding "In" bit may take a second or two to reflect the change. For the Internal Control Outputs, if an "Out" bit is active (1) but the "In" bit is not active after a second or two, a problem with that output is indicated. This is also true for the User Digital I/O Bits, however when an output is inactive (0), the corresponding input bit can indicate either a 1 (active) or 0 (inactive), depending upon the external status that is applied to the inputs.

Section 6 Model 4010 Calibration Setup

Before the Model 4010 can perform gas dilutions or calibrations, certain application-specific information must be entered. The following steps describe the basic set up operations that must be performed before using the 4010 for calibrations:

[1] Verify that all source and diluent gases that will be used for calibrations are present in the Gas Table supplied from the factory. If not, add gases as described on page 6-2.

[2] Set up a "Gas Standard" for each gas cylinder that will be attached to the source inlet ports, following the procedure described on page 6-3.

[3] Assign diluent gases and Gas Standards to the appropriate diluent and source inlet ports as described on page 6-5.

[4] If the User Digital I/O Bits are to be used for signaling the sequence status or for remote activation, the Digital I/O Groups must be set up as described on page 6-24.

[5] Set up calibration "Sequences" as described on Page 6-7. Sequences define the flow rates, concentrations, timing and other parameters for specific calibration sessions that are to be subsequently performed.

[6] If necessary, set the time and date to local time as described on page 6-30.

At this point, manual calibrations can be initiated. If automatically timed calibrations or calibrations initiated by the User Digital I/O Bits are desired, the following procedures may also be needed:

[7] If calibrations are to be automatically started at specific times, set up the sequence schedules as described on page 6-20.

[8] If calibrations are to be started by remote control using the User Digital I/O Bits, set up the Remote Activation information as described on pages 6-28 and/or 6-29.

The following pages describe these setup procedures in more detail.

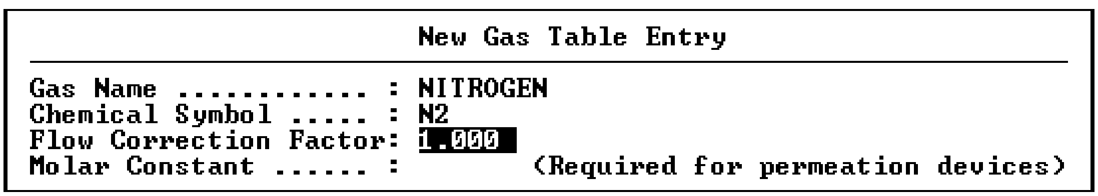
Set Up Gases

The Model 4010 is delivered from the factory with a Gas Table that contains the names, chemical symbols, flow correction factors and molar constants for commonly used gases. Ordinarily, it is not necessary to modify this table, however if a gas that will be used for calibrations is not included in the table, it will be necessary to add it. Gases may be added to the Gas Table as follows:

[1] Select Gases from the main menu and press the Enter button. A pop-up menu will appear.

[2] Select Gas Table and press the Enter button. Another pop-up menu will appear. This menu lists the following options: View to view the Gas Table, New to add a gas, Edit to modify a gas and Delete to remove a gas from the table.

[3] To add a gas, select New and press the Enter button. The New Gas Table Entry screen shown in Figure 6-1 will appear.


New Gas Table Entry

Gas Name .... : NITROGEN
Chemical Symbol ..... : N2
Flow Correction Factor: 1.000
Molar Constant ...... : (Required for permeation devices)

Figure 6-1 New Gas Screen

[4] Enter the name of the gas, its chemical symbol and a flow correction factor. If the gas is for a permeation device, the molar constant must also be entered.

[5] To save the gas, press the End Sequence button and answer yes to the confirming dialog box.

[6] If additional gases are needed, repeat steps 4 and 5.

[7] To return to the main menu, press the End Sequence button until only the main menu appears on the screen.

It may be desirable to delete unnecessary gases from the Gas Table in order to reduce the size of the selection list. The following steps will delete a gas from the Gas Table:

[1] From the main menu select Gases and press the Enter button. A pop-up menu will appear.

[2] Select Gas Table and press the Enter button. Select Delete and press the Enter button. The pop-up screen Delete Gas Table Entry will appear. By pressing Enter, a drop-down list of the gases in the Gas Table will appear.

[3] Select the gas you want to delete and press the Enter button. A screen with the prompt to delete or ignore will appear. If you wish to delete the gas, select yes and press the Enter button. To ignore, select the No and press the Enter button. This step may be repeated as necessary to delete additional gases.

Set up Gas Standards

Each compressed gas cylinder attached to a source inlet port must be set up as a "Gas Standard". Gas Standards may be set up as follows:

[1] Select Gases from the main menu and press the Enter button. A pop-up menu will appear.

[2] Select Gas Standards and press the Enter button. Another pop-up menu will appear. This menu lists the following options: View to view the Gas Standards, New to add a Gas Standard, Edit to modify a Gas Standard and Delete to remove a Gas Standard.

[3] To add a Gas Standard, select New and press the Enter button. The New Gas Standard screen shown in Figure 6-2 will appear.

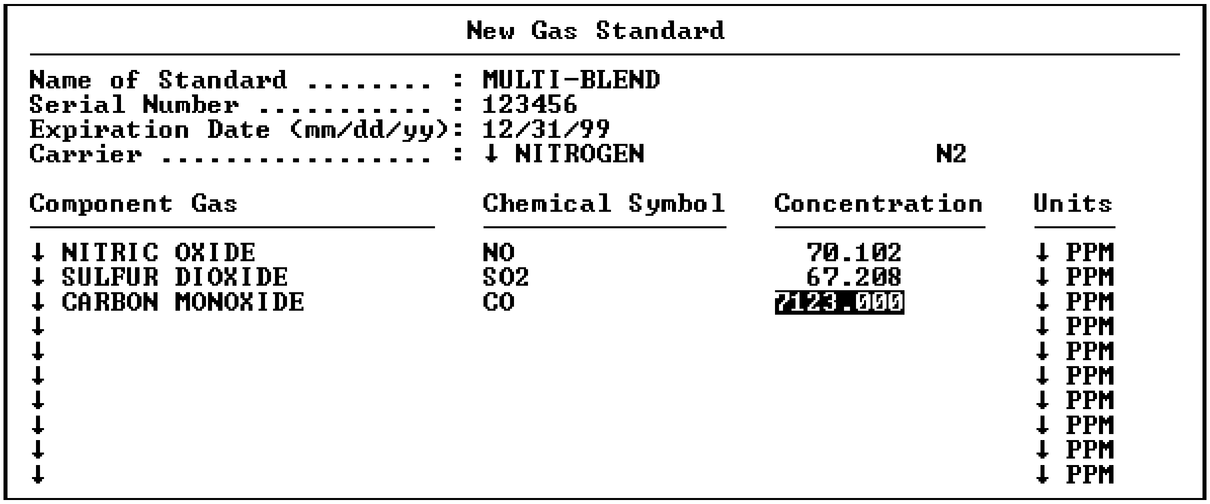


Figure 6-2 New Gas Standard Screen

[4] Enter a unique name for the Gas Standard, its serial number, its expiration date and the carrier gas.

[5] Select a gas for the first component by positioning the cursor over a Component Gas field and pressing Enter. Select a gas name and symbol from the drop-down list and press Enter to proceed to the concentration field. If a gas is not present in the list, it may be added by following the procedure on page 6-2.

[6] Enter the concentration of the gas in the cylinder. Be sure to observe the units of measure listed to the right. If you want to enter the gas in different units, move to the next field by pressing F3, change the units as described in step 7 and move back to the concentration field by pressing F2.

[7] By pressing Enter over the units for a gas, alternate units of measure for that gas component can be selected from a drop-down list. The concentration previously entered in the field will automatically be adjusted to the selected units.

[8] Repeat steps 5 and 6 until all components in the Gas Standard have been entered.

[9] To save the Gas Standard, press the End Sequence button and answer yes to the confirming dialog box.

[10] To create another Gas Standard, repeat steps 4 through 9.

[11] To return to the main menu, press the End Sequence button until only the main menu appears on the screen.

Diluent and Source Port Assignments

A diluent gas must be assigned to one or more diluent ports and a Gas Standard must be assigned to one or more source ports before dilution calibration sequences can be set up. To assign diluent gases and Gas Standards to inlet ports, use the following steps:

[1] Select Gases from the main menu and press the Enter button. A pop-up menu will appear.

[2] Select Port Assignments and press the Enter button. Another pop-up menu will appear. This menu lists the following options: View to view Port Assignments and Edit to modify the Port Assignments.

[3] Select Edit and press the Enter button. The Edit Port Assignments screen shown in Figure 6-3 will appear. This screen lists all the diluent ports and source ports installed in the unit (the standard 4010 has one diluent and three source ports). For each port, a drop-down selection box is available for selecting a gas or Gas Standard that is to be associated with that port.

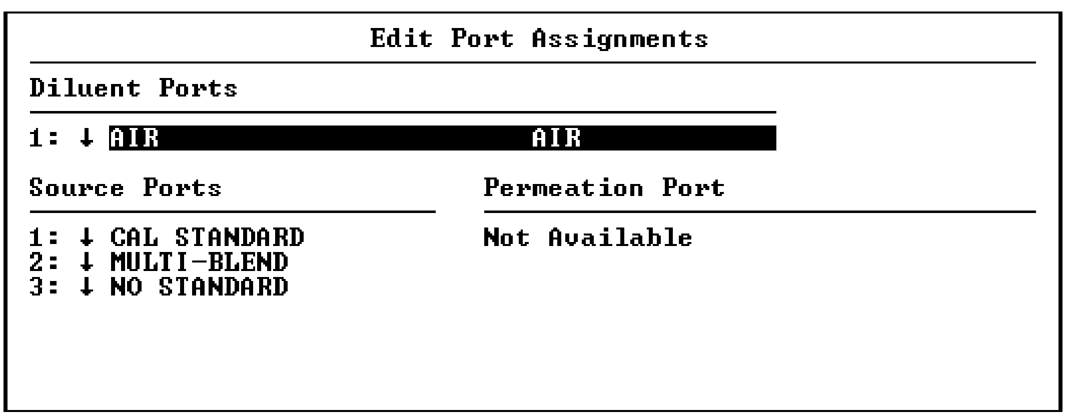


Figure 6-3 Edit Port Assignments Screen

[4] For each diluent port that will be used, select a diluent gas by positioning the cursor over the port's selection box and pressing Enter. A drop-down list will appear with your choices for the diluent gas. The diluent is usually air if a zero air generator is used for providing the diluent. Nitrogen or other cylinder gas may also be used, however if ozone or GPT calibrations are to be performed, the diluent must be air with the normal percentage of oxygen.

If the needed diluent gas is not listed, it may be added by performing the steps described in the "Set up Gases" section on page 6-2.

[5] For each Source Port that will be used, select a Gas Standard by positioning the cursor over the Source Port's selection box and pressing Enter. A drop-down list will appear with a list of Gas Standards. If the Gas Standard is not present in the drop-down list, it may be added by performing the steps described in the "Set up Gas Standards" section on page 6-3.

[6] To save the Port Assignments, press the End Sequence button and answer yes to the confirming dialog box.

[7] To return to the main menu, press the End Sequence button until only the main menu appears on the screen.

Introduction to Initializing Calibration Sequences

Calibration sequences are templates that are used for defining calibrations. Each sequence is composed of up to 20 calibration points, each point representing a concentration of a calibration gas. Sequences may be controlled externally, internally or may be used when performing manual calibrations. The calibration sequences are stored in non-volatile memory for usage at a later time.

The Model 4010 supports four types of calibration sequences. These sequences are:

Gas Dilution A metered quantity of source gas is diluted with a metered quantity of diluent. Note: The source gas could be from a multiple blend cylinder.

Ozone	A metered quantity of diluent is irradiated by a precisely controlled ultraviolet lamp in order to produce ozone.
Gas Phase Titration	A metered quantity of source gas is diluted with a metered quantity of ozonated diluent.
Permeation	A metered quantity of permeation source gas is diluted with a metered quantity of diluent.
Multi-Gas Sequence	Each point of a Multi-Gas Sequence may be of a different type and use a different source gas.

The first four sequence types may be used when all points in the sequence represent the same type and the same source gas. The Multi-Gas Sequence, though more difficult to set up than the other types, provides the most flexibility, allowing the Gas Standard, gas component, source MFC and Instrument Solenoids to be independently selected for each point. This allows multiple types of calibrations to be performed from within the same sequence.

A number of things should be considered when defining calibration sequences:

- Ozone concentrations used in ozone and GPT calibrations are most precise when the diluent flow is set the same as that used for calibration of the ozone generator. Factory calibrations of the ozone generator are performed at 4,900 cc/min of diluent and 100 cc/min of ozone flow for a total flow of 5,000 cc/min.
- High instrument flows limit the range of the diluting process and result in higher source gas usage.
- Up to 20 calibration sequences may be predefined with up to 20 calibration points allowed per sequence.
- Overly complex auto calibration sequences result in significant amounts of down time while instruments are undergoing calibration.

Auto Calibrations may occur in one of three ways. The first method is "Scheduled", in which the 4010 automatically initiates the calibration sequence at a specified time and steps through each calibration point. The second method is "Remote Point Activation", in which an external device initiates and steps the 4010 through each calibration point, and third, "Remote Sequence Activation", in which an external device initiates a calibration sequence, but the 4010 then takes over and steps through each calibration point.

There are 24 User Digital I/O Bits available. These bits can be assigned to control calibration sequence initiation and for stepping though calibration points or for sensing when calibrations are active. The bits are normally open, which is signified with a 0. A 1 signifies the bit is active or the calibration point or sequence is active.

Defining Calibration Sequences

Calibration sequences are defined in a multi-page dialog box that is 3 pages long for most sequence types and 5 pages for Multi-gas sequences. The page down and page up keys (F5 and F4, respectively) may be used to switch from page to page. The first page contains information common to all calibration points. Pages 2 through 3 (or 5) contain the information for the individual calibration points.

To set up page 1 of a calibration sequence, perform the following steps:

[1] From the main menu, select Sequences, and press the Enter button. A pop-up menu will appear.

[2] Select New and press the Enter button. The pop-up screen, New Sequence (Page 1 of 3) will appear.

```
                         New Sequence (Page 1 of 3)

Sequence Name: DAILY ZERO/SPAN

Sequence Type: (*) Gas Dilution           Running Order: (*) Ascending
               ( ) Ozone                                 ( ) Descending
               ( ) Gas-Phase Titration
               ( ) Multi-gas Sequence                        Instrument
                                                             Solenoids

Diluent Gas: ↓ AIR                                             1[ ]
Source  Gas: ↓ MULTI-BLEND                                     2[X]
Primary Gas: ↓ SO2                                             3[ ]
Source  MFC: ↓ SOURCE 1                                        4[ ]
                                                               5[ ]
Minimum Instrument Flow:   5.000 SLPM                          6[ ]
Conditioning Period .. :  5 Minutes

                         1      8 9     16 17    24
                         ........ ........ ........            More ...
```

Figure 6-4 New Sequence Screen, Page 1

[3] Enter a unique name for the sequence. Up to 20 characters may be used. Press the Enter button when the full name has been entered. This moves you to the area called Sequence Type.

[4] Select the appropriate sequence type. Choices are Gas Dilution, Ozone, Gas Phase Titration and Multi-gas Sequence. If the 4010 includes a Permeation Oven option, a Permeation choice will also be available. Select your choice and press the Enter button. This moves you to the area called Running Order. Note that data entry fields that are irrelevant for the selected sequence type will disappear.

[5] Select the order in which the calibration points are to run. The choices are Ascending and Descending. The points will be activated in ascending or descending order of the point number; not necessarily in the order of the concentrations. If for example points 1 through 5 were entered as 400, 300, 200, 100, 50, respectively, and you selected Ascending they would run in this order. If you selected Descending, the 50 point would be activated first, then 100, etc. Press the Enter button when your choice is made. You will be moved to the area for selecting the diluent gas.

[6] By pressing the Enter button while in the diluent gas field, the gas choices will appear in a drop-down list. Choose the correct diluent and press the Enter button. If the diluent that you need is not in the list, it can be added as described on page 6-2. The field that you are moved to will depend upon the sequence type selected earlier. For Dilution, GPT and Permeation types, the next field will be the Source Gas. For Ozone and Multi-gas types, you will be moved directly to the Minimum Instrument Flow field.

[7] If you are moved to the Source Gas field, press Enter to drop down a list of Gas Standards that are currently associated with the source inlet ports. If the Gas Standard that you need is not in the list, it can be added as described on page 6-3 and/or assigned to a source port as described on page 6-5. Select the appropriate Gas Standard with the arrow keys and press Enter to move to the next field.

[8] Once you have selected the Gas Standard, you will be moved to a field that allows you to select one of the gas components for that standard. Press Enter to drop down the list, select a gas with the arrow keys and press Enter again to move to the next field. If the needed component is not present, it can be added to the Gas Standard as described on page 6-3.

[9] For Dilution and GPT sequence types, you will be moved to a field that allows you to select a source mass flow controller that best suits the gas you are diluting (the standard 4010 has only one source MFC and therefore only one choice). Choose and MFC by pressing Enter to drop down the list, selecting the MFC with the arrow keys and pressing Enter again to move to the next field.

[10] When you are moved to the area of the screen that asks for the Minimum Instrument Flow, enter the minimum total flow necessary not only to supply calibration gas to all attached instruments, but also to provide an excess flow from the outlet manifold's vent. Pressing the Enter button confirms your entry and moves you to an area of the screen called Conditioning Period.

[11] Enter the conditioning time needed, in minutes. This is the amount of time you want the calibrator to begin blending and/or producing span gas or zero air before activating the Instrument Solenoid controlling the device you are calibrating. Press the Enter button when you have entered the duration. This takes you to an area called Sequence Status Output.

[12] If you have previously assigned User Digital I/O Bits to Sequence Status Outputs you will be prompted to select which status outputs are associated with this sequence. Bit positions indicated by a 1 or a 0 have been reserved for Sequence Status Outputs and are available to signal an external device when this calibration sequence is active. Bit positions indicated by a decimal point have been assigned to other purposes and may not be changed here. If all the bits are indicated by decimal points and this feature is needed, then Sequence Status Output bits must be assigned in the Digital I/O Group Assignments screen under the Remote Activation menu (see Page 6-23).

A 1 or a 0 can be inserted in each bit location that is not indicated by a decimal point. When this sequence is subsequently activated, the pattern of 1's and 0's will be presented on the User Digital I/O Bits as lows (0V) and highs (5V), respectively. After you have inserted your bit pattern, press the Enter button. You will be moved to the Instrument Solenoids area of the screen.

[13] The Instrument Solenoids are +24 Volt drivers for activating external devices such as air quality analyzer zero/span valves. Move the cursor over the bit(s) you want to activate and press the "+" key to set, "-" key to clear or Space to toggle the "X" indicator in the box. All instrument solenoids indicated by an "X" will be activated (that is, 24 Volts will be applied) after the specified conditioning period has elapsed for this sequence. After you have entered the instrument solenoid drivers associated with the sequence being initialized, press the Page Down button (F5) to proceed to page 2.

You have completed Page 1 of the New Sequence programming. If this is a Multi-gas Sequence, you should proceed to page 6-15, which describes how to set up pages 2 through 5 of a Multi-gas sequence. Otherwise, continue on to the next section, which describes how to set up pages 2 and 3 of single gas sequences.

Setting up Sequence Points for Single-Gas Sequences

(Pages 2 and 3)

The following paragraphs are a continuation of the steps describing how to set up page 1 of a sequence in the section "Defining Calibration Sequences" beginning on page 6-8 and ending on page 6-12. The steps that follow assume the user has not chosen "Multi-gas Sequence" as the sequence type.

[14] After pressing the F5 key to move to Page 2 of the Sequence setup, the screen shown in Figure 6-5 will appear.

New Sequence (Page 2 of 3) More ...

Point	Concentration Primary (↓PPB)	Ozone (PPB)	Duration (Minutes)	Point Status Outputs 1 8	9 16	17 24
1	0	0	15	....	0001	....
2	500	0	15	....	0010	....
3	500	400	15	....	0011	....
4	500	300	15	....	0100	....
5	500	200	15	....	0101	....
6	500	100	15	....	0110	....
7	500	50	15	....	0111	....
8				....	0000	....
9				....	0000	....
10				....	0000	....

More ...

Figure 6-5 New Sequence Screen (Single Gas, Page 2 of 3)

The cursor will initially be in the units field for the primary gas concentration. By pressing Enter or the down arrow while the cursor is in the units field, the preferred engineering units for concentrations in this sequence may be selected from a drop-down list (%, PPM, PPB, or PPT). All primary gas and ozone concentrations in this sequence will be expressed in the selected units. Pressing the Enter key or F3 will proceed to the next field.

[15] After exiting the units selection field, the cursor will be moved to a field for entering either the Primary or Ozone concentration for point 1, depending upon the Sequence Type that was selected on Page 1. If Gas Dilution, Gas Phase Titration or Permeation was selected, you will be in the column for entering the Primary concentration. If Ozone was selected, the column of fields for entering primary gas concentrations will be disabled and you will be moved directly to the column for entering the Ozone concentration.

Enter the primary gas (or ozone) concentration for this point. Remember which units you selected for concentration so that your input is correct. If the number is not in the proper units, you will probably be prompted with a pop-up box showing what the range of concentrations must be for your entry. Enter the number and press the Enter button. You will now be moved either to the Duration column of this screen or to the ozone column if this is a GPT sequence type.

If this is a GPT sequence, enter an ozone concentration. The ozone concentration should be set to the amount of NO2 desired in the output gas for this point and should be less than the primary gas (NO) concentration. After entering the ozone, press Enter to move to the Duration field.

Note that, regardless of the allowable range for primary gas and ozone concentrations, zero (0) may be entered. If zero is entered for the primary gas concentration, the 4010 will automatically turn off all source inlet valves to assure that this is truly a "Zero" point. Likewise, for Ozone and GPT sequences, if the ozone concentration is set to zero, the ozone generator will be turned off.

[16] Enter the number of minutes that you wish this calibration point to remain active when the sequence is timer stepped. Press the Enter button and you will either be moved to the next point or to the Point Status Outputs area of the screen if you previously assigned the Point Status Outputs in the Digital I/O Group Assignments screen (page 6-23).

[17] If you have previously assigned User Digital I/O Bits to Point Status Outputs you will be prompted to select which status outputs are associated with this particular calibration point. Bit positions indicated by a 1 or a 0 have been reserved for Point Status Outputs and are available to signal an external device when this calibration point is active. Bit positions indicated by a decimal point have been assigned to other purposes and may not be changed here. If all the bits are indicated by decimal points and this feature is needed, then Sequence Status Output bits must be assigned in the Digital I/O Group Assignments screen under the Remote Activation menu (see Page 6-23).

A 1 or a 0 can be inserted in each bit location that is not indicated by a decimal point. When this point is subsequently activated, the pattern of 1's and 0's will be presented on the User Digital I/O Bits as lows (0V) and highs (5V), respectively. After you have inserted your bit pattern, press the Enter button. You will be moved to primary gas (or ozone) concentration field for the next point.

[18] Repeat steps 15 through 17 until each calibration point for this sequence has been entered. If there more than 10 points in this sequence, press F5 after you have entered the first 10 points. This takes you to page 3, which allows you to program an additional 10 calibration points.

[19] When all points have been defined, the sequence information can be reviewed by pressing F4 and F5 to page up and page down. Information can be edited by positioning the cursor using the F2 and F3 key to move backward or forward between fields and then entering the new information in the highlighted field.

When finished, press End Sequence from any page. A message will pop up asking if you want to save the sequence. Responding "yes" will save the sequence information you have entered into non-volatile memory. Answering "no" will exit, discarding any information that has been entered. Pressing End Sequence again will return you to the New Sequence screen without saving or discarding information.

Setting up Sequence Points for Multi-gas Sequences (Pages 2 - 5)

Unlike the other sequence types, Multi-gas sequences don't assume that each point is of the same type and gas source. Consequently, certain information that is entered on the first page and is common to all points for single-gas sequences is entered for each point of a Multi-gas sequence. In particular, the Gas Source, Primary Gas Name, Source MFC and Instrument Solenoids can be independently programmed for each point of a Multi-gas sequence. Figure 6-6 shows page 2 of a typical multi-gas screen.

New Sequence (Page 2 of 5) More ...

Point	Gas Source	Gas Name	Source MFC	Concentration Primary (↓PPB)	Concentration Ozone (PPB)	Duration (Min)
1	↓ <Zero>	↓		0	0	15
2	↓ MULTI-BLEND	↓ SO2	1	450	0	15
3	↓ <Zero>	↓		0	0	15
4	↓ NO STANDARD	↓ NO	1	450	0	15
5	↓ <Zero>	↓		0	0	15
6	↓ NO STANDARD	↓ NO	1	500	0	15
7	↓ NO STANDARD	↓ NO	1	500	450	15
8	↓ <Zero>	↓		0	0	15
9	↓ <Ozone>	↓		0	450	15
10	↓ <Zero>	↓		0	0	15

More ...

Figure 6-6 New Sequence Screen (Multi-gas, Page 2 of 5)

The additional information makes it necessary for the point information to be presented on four pages, where a single-gas sequence needs only two. Pages 2 and 3 define the first ten points, while 4 and 5 define points 11 through 20. Most of the information is presented on pages 2 and 4, but the Instrument Solenoid and Point Status Output information is found on pages 3 and 5, as shown in Figure 6-7.

The following paragraphs are a continuation of the steps describing how to set up page 1 of a sequence in the section "Defining Calibration Sequences" beginning on page 6-8 and ending on page 6-12. The steps that follow assume the user has chosen "Multi-gas Sequence" as the sequence type.

[14] After pressing the F5 key on page 1 to move to Page 2 of a Multi-gas sequence, the setup screen shown in Figure 6-6 will appear.

The cursor will initially be in the units field for the primary gas concentration. By pressing Enter or the down arrow while the cursor is in the units field, the preferred engineering units for concentrations in this sequence may be selected from a drop-down list (%, PPM, PPB, or PPT). All primary gas and ozone concentrations in this sequence will be expressed in the selected units. Pressing the Enter key or F3 will move you to the Gas Source field of the first point.

[15] A Gas Source must be selected for each point by pressing Enter to drop down a list of Gas Standards that are currently associated with the source inlet ports. In addition to the Gas Standards are the special symbols "<Zero>", "<Ozone>" and, if a perm oven is installed, "<Permeation>". If the Gas Standard that you need is not in the list, it can be added as described on page 6-3 and/or assigned to a source port as described on page 6-5. Select the appropriate Gas Standard or one of the special symbols with the arrow keys and press Enter to move to the next field.

If a Gas Standard or "<Permeation>" is selected, the cursor will move to the Gas Name field. If "<Ozone>" is selected as the Gas Source, the cursor will jump directly to the ozone concentration field, skipping the fields that are irrelevant for ozone concentrations. Likewise, selecting "<Zero>" will skip all the way to the Duration field and set the primary gas and ozone concentrations to zero.

[16] If you have selected a Gas Standard or "<Permeation>" as the Gas Source, you will be moved to the Gas Name field where a primary gas can be selected from a list of components for that Gas Standard (or Perm Oven). Press Enter to drop down a list of gas components, select a gas with the arrow keys and press Enter again to move to the next field. If the needed component is not present, it can be added as described on page 6-3.

[17] For Dilution and GPT sequence types, you will be moved to a field that allows you to select a source mass flow controller that best suits the gas you are diluting. Enter "1" or "2" here to select the desired MFC and press Enter to proceed. The standard 4010 has only one source MFC, making "1" the only choice.

[18] Unlike single-gas sequences, where the sequence type is specified on page 1, Multi-gas sequences determine the type of each point by what information is entered. If a special symbol is selected for the Gas Source, the type for that point is determined by the symbol. If a Gas Standard is selected for the Gas Source, the following rules apply:

- If the ozone is set to zero or left blank, the point is considered a Dilution type.
- If the primary gas concentration is zero or left blank and there is an ozone concentration, the point is considered an Ozone type.
- If a concentration is entered for both the primary gas and ozone, the point is assumed to be a GPT type.

Keeping these rules in mind, enter the primary gas and ozone concentrations for this point (leaving a field blank is equivalent to entering zero). Remember which units you selected for concentration so that your input is correct. If the number is not in the proper units, you will probably be prompted with a pop-up box showing what the range of concentrations must be for your entry. After entering each number, press the Enter button. After entering both concentrations, you will now be moved to the Duration column.

Note that, regardless of the allowable range for primary gas and ozone concentrations, zero (0) may be entered. If zero is entered for the primary gas concentration (or if "<Zero>" is selected as the Gas Source), the 4010 will automatically turn off all source inlet valves to assure that this is truly a "Zero" point. Likewise, if the ozone concentration is set to zero, the ozone generator will be turned off.

[19] Enter the number of minutes that you wish this calibration point to remain active when the sequence is timer stepped. Press the Enter button and you will be moved to the Gas Source field of the next point.

[20] Repeat steps 15 through 19 until all calibration points for this sequence have been defined or until all 10 points on the page have been entered. When page 2 is completed, press F5 to proceed to page 3.

[21] Figure 6-7 shows page 3 of a multi-gas sequence. Pages 3 and 5 contain only two editable fields for each point; the Gas Names and the Primary and Ozone concentrations are presented only for reference.

New Sequence (Page 3 of 5) More ...

Point	Gas Name	Concentration Primary (PPB)	Ozone (PPB)	Instrument Solenoid 1 6	Point Status Outputs 1 8	9 16	17 24
1	<Zero>	0	0	100000	....	0001	....
2	SO2	450	0	100000	....	0010	....
3	<Zero>	0	0	010000	....	0011	....
4	NO	450	0	010000	....	0100	....
5	<Zero>	0	0	010000	....	0101	....
6	NO	500	0	010000	....	0110	....
7	NO	500	450	010000	....	0111	....
8	<Zero>	0	0	001000	....	1000	....
9	<Ozone>	0	450	001000	....	1001	....
10	<Zero>	0	0	111000	....	1010	....

More ...

Figure 6-7 New Sequence Screen (Multi-gas, Page 3 of 5)

Initially, the cursor will be positioned on the first Instrument Solenoid field. Rather than using check-boxes, as in page one of single-gas sequences, multi-gas instrument solenoids are entered like digital I/O's, where a "1" means "on" and "0" means "off". After you have finished entering a "1" for each instrument that is to be activated for this point, press Enter to proceed to the next field.

[22] If you have previously assigned User Digital I/O Bits to Point Status Outputs you will be prompted to select which status outputs are associated with this particular calibration point. Bit positions indicated by a 1 or a 0 have been reserved for Point Status Outputs and are available to signal an external device when this calibration point is active. Bit positions indicated by a decimal point have been assigned to other purposes and may not be changed here. If all the bits are indicated by decimal points and this feature is needed, then Sequence Status Output bits must be assigned in the Digital I/O Group Assignments screen under the Remote Activation menu (see Page 6-23).

A 1 or a 0 can be inserted in each bit location that is not indicated by a decimal point. When this point is subsequently activated, the pattern of 1's and 0's will be presented on the User Digital I/O Bits as lows (0V) and highs (5V), respectively. After you have inserted your bit pattern, press the Enter button. You will be moved to Instrument Solenoid field for the next point.

[23] Repeat steps 21 and 22 until all the Instrument Solenoids and Point Status Outputs have been set up for each calibration point or until all 10 points on the page have been entered. If there more than 10 points in this sequence, press F5 after you have entered the first 10 points. This takes you to page 4, which allows you to program an additional 10 calibration points.

[24] When all points have been defined, the sequence information can be reviewed by pressing F4 and F5 to page up and page down. Information can be edited by positioning the cursor using the F2 and F3 key to move backward or forward between fields and then entering the new information in the highlighted field.

When finished, press End Sequence from any page. A message will pop up asking if you want to save the sequence. Responding "yes" will save the sequence information you have entered into non-volatile memory. Answering "no" will exit, discarding any information that has been entered. Pressing End Sequence again will return you to the New Sequence screen without saving or discarding information.

Auto Calibration Set-up

Once calibration sequences have been set up, they can be manually initiated by selecting either the "Operator Stepped" or "Timer Stepped" option from the "Run" item of the Sequence menu. In addition, calibrations can be automatically initiated. The three modes of automatic calibration available to Model 4010 users are "Scheduled", "Remote Sequence Activation" and "Remote Point Activation".

Scheduled sequences are configured under the Schedule area of the Sequences menu as described on page 6-21. For Scheduled sequences, the 4010 timer is used to initiate a sequence at a particular time and date. The sequence is then automatically stepped through all calibration points using the duration programmed for each point when the sequence was set up.

Scheduled sequences can also be programmed to automatically repeat at selected intervals.

For Remote Sequence Activation, User Digital I/O Bits must first be assigned to the "Sequence Control Input" digital I/O group as described on page 6-23. A unique pattern of Sequence Control Inputs, a "Sequence Start Pattern", is then assigned to each sequence that is to be remotely activated (see page 6-26). When one of the Sequence Start Patterns is detected on the User Digital I/O Bits, the sequence assigned to that pattern will be activated. The 4010 timer then takes control and steps through each calibration point using the point duration for timing.

For Remote Point Activation, User Digital I/O Bits must not only be assigned to the Sequence Control Input digital I/O group, but also to the "Point Control Input" group as described on page 6-23. As for Remote Sequence Activation, a Sequence Start Pattern must be first assigned to each sequence that will be remotely activated (page 6-26). In addition, a "Point Start Pattern" must be assigned to each point of each sequence that is to be activated as described on page 6-27. When a Sequence Start Pattern and a Point Start Pattern is detected simultaneously on the User Digital I/O Bits, the selected point of the indicated sequence will be activated. The point will remain active as long as the pattern is present on the I/O bits. Unlike the other Auto Calibration options, the sequence is not automatically stepped for Remote Point Activation; the remote controlling device is responsible for stepping the calibrator through each calibration point by changing the Point Start Patterns.

Scheduling Automatic Calibrations

To set-up the Model 4010 for Scheduled Auto Calibration, perform the following steps:

[1] Configure calibration sequences as described in the section titled "Defining Calibration Sequences", on page 6-8.

[2] If necessary, set the time and date to the correct local time as described on page 6-29.

[3] From the main menu select Sequences and press the Enter button. A pop-up menu will appear. Select Schedule and press the Enter button. The Edit Sequence Schedules screen will appear, as shown in 6-8.

Edit Sequence Schedules

Sequence Name	Enabled	- Next Start - mm/dd/yy	hh:mm	Frequency Days	hh:mm
DILUTION	[X]	12/18/97	23:45	1	00:00
GPT	[X]	12/19/97	00:15	1	00:00
MULTI-GAS	[ ]	01/01/98	01:45	30	00:00
OZONE	[X]	12/19/97	00:45	1	00:00

Figure 6-8 The Edit Sequence Schedules Screen

[4] From the Edit Sequence Schedules screen, arrow down to the sequence you want to schedule. Note: All sequences that have been initialized in the 4010 will be listed in the Edit Sequence Schedules Screen under the Sequence Name. Place an X in the Enabled area of the screen to activate the scheduling for that sequence.

[5] Next fill in the day, month, year, hour and minute under Next Start, for the time and date you wish the sequence to be activated. Note that when the screen is saved, if any of the Next Start times that were entered are found to be in the past, they will be automatically advanced by the Frequency until they are in the future. Also, any time a scheduled sequence is automatically activated, the Next Start time will be updated by adding the Frequency.

[6] Next fill in, under Frequency, the days, hour and minutes that should elapse between each automatic starting of the sequence. The frequency for days can be 0 through 365 days. For performing this calibration every day a 1 would be entered in Days. If the calibration is to occur at the same time every day, the hours and minutes should be set to "00:00". If the days, hours and minutes are all set to zero, the sequence will only run once at the indicated Next Start time and will not repeat,

[7] Repeat steps 4 through 6 as necessary to schedule other sequences.

[8] When all of the sequences have been scheduled, press the End Sequence button. You will be prompted to save the information or not. The cursor will be on the "Y" for saving. Press the Enter button and the initialization will be saved. If you wish to discard the new initialization, arrow to the "N" and press the Enter button.

Digital I/O Group Set-up

If the User Digital I/O is to be used for signaling sequence status or for remotely activating sequences or sequence points, each of the 24 bits must be assigned to their respective purposes before these functions can be activated.

The 24 User Digital I/O Bits can be activated remotely by an external device, such as a data acquisition system or they can be used to signal the external device of when a sequence and/or its calibration points are active. In other words, the 24 bits can be used as control inputs or status outputs.

Each bit is active-low pulled up to 5 Volts. This means that, when the bit is inactive, as indicated by a "0" on the status screens, a voltmeter measuring the rear panel pin corresponding to that bit will measure high; approximately 5 Volts. When the 4010 or an external controlling device activates a bit, as indicated by a "1", the pin will be pulled low; close to 0 Volts.

There are five "Digital I/O Groups", each group serving a different purpose. Three groups are for controlling calibrations remotely and two are for signaling the status of calibrations in progress. Each bit may only be assigned to one group. The Digital I/O Groups are:

Abort Control Input — Normally, only one bit is assigned to this group. When the bit is active (low), any sequences in progress will be terminated.

Sequence Control Inputs — These inputs are used for Remote Sequence Activation (see page 6-21) or in conjunction with the Point Control Inputs for Remote Point Activation. Each sequence that is to be remotely activated should have a unique pattern of Sequence Control Inputs.

Point Control Inputs

These inputs are used in conjunction with the Sequence Control Inputs for Remote Point Activation (see page 227). Each point that is to be remotely activated within a particular sequence should have a unique pattern of Point Control Inputs for that sequence. Point Control Input patterns must be unique within each sequence, but the same pattern may be used for different sequences.

Sequence Status Outputs

These bits are configured as outputs which signal when a particular sequence is active. The bit pattern that is produced on the output depends upon what was entered during sequence setup. More information about setting up Sequence Status Outputs may be found in the section starting on page 8.

Point Status Outputs

These bits are configured as outputs which signal when a particular point within a sequence is active. The bit pattern that is produced on the output depends upon what was entered during sequence point setup. Pages 14 and 18 contain more information about setting up Point Status Outputs.

When setting up the digital I/O Groups, remember that no bit may be assigned to more than one group. To assign a bit to a group, first move the cursor to the correct bit position by using the arrow keys and then press "1" (to un-assign a bit, press "0").

This bit pattern information should be used when mapping the input connections to connector pins or wires when installing the Model 4010 as described in Section 4, Installation.

The Digital I/O Groups may be set up by the following procedure:

[1] Select Sequences under the main menu and press the Enter button. A pop-up menu will appear.

[2] Select Remote Activation from the menu. A pop-up menu will appear.

[3] Select Digital I/O Groups from the pop-up menu and press the Enter button. The Edit Digital I/O Group Assignments screen will appear, as shown in Figure 6-9.

```
              Edit Digital I/O Group Assignments

                                          Digital I/O Bits
        Group Category            1        8 9       16 17    24

Abort    Control Input :          ........ ........ 00000001
Sequence Control Inputs:          1111.... ........ 0000000.
Point    Control Inputs:          ....1111 ........ 0000000.
Sequence Status Outputs:          ........ 1111.... 0000000.
Point    Status Outputs:          ........ ....1111 0000000.

Notes:
Press 1 or Y to assign a bit.
Press 0 or N to unassign a bit.
Each bit can be assigned to only one category.
```

Figure 6-9 The Edit Digital I/O Group Assignments Screen

[4] If a separate Abort Control Input is needed (that will be used to terminate a sequence), initialize it by setting the desired bit to "1". When finished, press Enter to proceed to the next field.

[5] Identify the bits that will be used for Remote Sequence Activation by setting the bits to "1", then press Enter to proceed to the next field.

[6] Identify the bits that will be used for Remote Point Activation by setting the bits to "1", then press Enter to proceed to the next field.

[7] Identify the bits that will be used as Sequence Status Outputs by setting the bits to "1", then press Enter to proceed to the next field.

[8] Identify the bits that will be used as Point Status Outputs by setting the bits to "1", then press Enter to proceed to the next field.

[9] When all of the I/O bits have been identified, press the End Sequence button. You will be prompted to save the information or not. The cursor will be on the "Y" for saving. Press the Enter button and the initialization will be saved. If you wish to discard the new initialization, arrow to the "N" and press the Enter button.

Assigning Sequence Start Patterns

Any of the 20 possible sequences may be activated when the Model 4010 is configured for Remote Sequence Activation.

To set-up the Model 4010 for Remote Activation Calibration, perform the following steps:

[1] Configure calibration sequences as described in the section titled "Defining Calibration Sequences", on page 6-8.

[2] Select Sequences under the main menu and press the Enter button. A pop-up menu will appear.

[3] Select Remote Activation from the menu. A pop-up menu will appear.

[4] Select Sequence Start and press the Enter button. The Sequence Start Remote Activation Patterns screen shown in Figure 6-10 will appear.

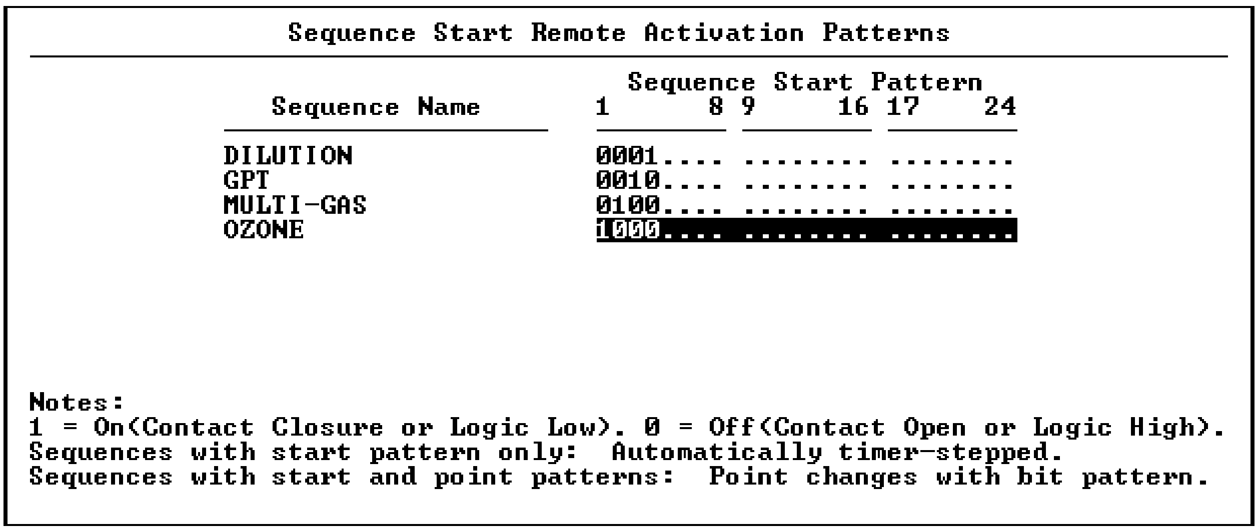


Figure 6-10 Sequence Start Remote Activation Patterns Screen

Notice that some of the bits are set to either "0" or "1" and the rest are indicated by decimal points. The bits indicated by "0" or "1" have previously been assigned as Sequence Control Inputs and may be used for entering bit patterns. If all the bits are indicated by decimal points, then set up the Sequence Control Input group as described on page 6-23 in the section Digital I/O Group Set-up.

[5] The sequences that have been initialized and saved will be listed in this screen under Sequence Name. Arrow down to the sequence whose start bit pattern you wish to initialize.

[6] Assign a unique bit pattern that will be used to start this sequence by entering 1's or 0's. When finished, press Enter or an arrow key to move to another sequence.

[7] Repeat steps 5 and 6 as necessary until a unique pattern has been assigned to each sequence that will be remotely activated.

[8] When finished, press the End Sequence button. You will be prompted to save the information or not. The cursor will be on the "Y" for saving. Press the Enter button and the initialization will be saved. If you wish to discard the new initialization, arrow to the "N" and press the Enter button.

Assigning Point Start Patterns

Any points in any of the 20 possible sequences may be activated by means of the User Digital I/O Bits when the Model 4010 is configured for Remote Point Activation.

To set-up the Model 4010 for Remote Point Activation, perform the following steps:

[1] Configure calibration sequences as described in the section titled "Defining Calibration Sequences", on page 6-8.

[2] In order to remotely activate a point, the sequence containing the point must have a unique Sequence Start Pattern assigned to it. The Sequence Start Pattern is used in conjunction with the Point Start Pattern to uniquely identify a point to activate. If not already done, assign a Sequence Start Pattern as described on page 6-24.

[3] Select Sequences under the main menu and press the Enter button. A pop-up menu will appear.

[4] Select Remote Activation from the menu. Another pop-up menu will appear.

[5] Select Point Start and press the Enter button. A list of sequences will be presented.

[6] Select the name of the sequence whose points you want to assign Point Start Patterns to. The Point Start Remote Activation Patterns screen shown in Figure 6-11 will appear.

Point Start Remote Activation Patterns

Point	Point Start Pattern 1 – 8	9 – 16	17 – 24	Point	Point Start Pattern 1 – 8	9 – 16	17 – 24
1	0001	....	....	11	1011	....	....
2	0010	....	....	12	1100	....	....
3	0011	....	....	13	0000	....	....
4	0100	....	....	14	0000	....	....
5	0101	....	....	15	0000	....	....
6	0110	....	....	16	0000	....	....
7	0111	....	....	17	0000	....	....
8	1000	....	....	18	0000	....	....
9	1001	....	....	19	0000	....	....
10	1010	....	....	20	0000	....	....

Notes:
1 = On(Contact Closure or Logic Low). 0 = Off(Contact Open or Logic High).
Sequences with start pattern only: Automatically timer-stepped.
Sequences with start and point patterns: Point changes with bit pattern.

Figure 6-11 Point Start Remote Activation Patterns Screen

Notice that some of the bits are set to either "0" or "1" and the rest are indicated by decimal points. The bits indicated by "0" or "1" have previously been assigned as Point Control Inputs and may be used for entering bit patterns. If all the bits are indicated by decimal points, then set up the Point Control Input group as described on page 6-23 in the section Digital I/O Group Set-up.

[7] Each of the 20 possible points are shown on the screen. Arrow down to the point whose Point Start Pattern you wish to set up.

[8] Enter the unique bit pattern that will be used to activate this point by entering 1's or 0's. When finished, press Enter or an arrow key to move to another point.

[9] Repeat steps 7 and 8 as necessary until a unique pattern has been assigned to each remotely activated point.

[10] When finished, press the End Sequence button. You will be prompted to save the information or not. The cursor will be on the "Y" for saving. Press the Enter button and the initialization will be saved. If you wish to discard the new initialization, arrow to the "N" and press the Enter button.

Setting the Time and Date

To set the time and date, perform the following steps:

[1] From the main menu select System and press the Enter button. A pop-up menu will appear.

[2] Select Set Clock and press the Enter button. The screen shown in Figure 6-12 will appear.

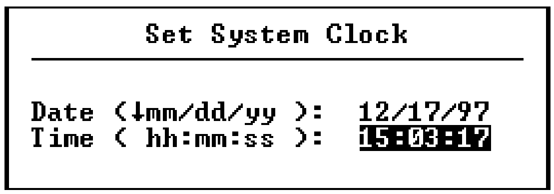


Figure 6-12 Set System Clock Screen

[3] Select the desired date format that will be used in all 4010 screens. The options are mm/dd/yy, dd/mm/yy and yy/mm/dd, with either a "/" or "-" as the separator character.

[4] Set the Date and Time by entering the date and time. It is not necessary to enter the "/" or ":" separator characters.

[5] Upon completion, press the End Sequence button. You will be prompted to save the information or not. The cursor will be on the "Y" for saving. Press the Enter button and the initialization will be saved. If you wish to discard the new initialization, arrow to the "N" and press the Enter button.

Upon saving, the time and date are written to the internal battery backed clock.

Section 7 Serial Communications

The Model 4010 incorporates two serial RS-232 ports, which can be attached to a modem or personal computer for remote configuration, operation, control and for updating the operating program.

The remote terminal feature allows a user to remotely interact with the 4010. While in this "terminal mode", the user can view an exact image of the 4010’s display on a remote terminal screen and access any function that is available on the unit’s front panel.

The Model 4010's operating software and user configurations are contained in flash EPROM, a solid-state non-volatile type of memory that is configured to emulate a hard disk drive. These program or configuration files can be easily updated via the communications link, eliminating the need to physically change EPROMs or cards in order to incorporate new software features.

In addition to terminal mode, the Model 4010 supports a serial command mode. This mode makes it possible to interact with the unit via the serial communications port using a protocol more suitable for remote control by a computer.

Using serial commands, sequences and points can be started or stopped and several other 4010 features can be accessed. This capability opens up a number of applications involving remote control of the Model 4010 by local or remotely located PCs or direct control by a datalogger.

Operating Modes

There are two modes of operation for the serial ports: terminal mode and command mode. Terminal mode allows a user to interact with the 4010 using a remote terminal. Command mode allows another computer or datalogger to control and monitor the 4010 using a command protocol. Both operating modes may be used on the same serial port, however the correct mode of operation must be selected first. Following are descriptions of how to change modes.

Terminal Mode

If the remote terminal is enabled when the 4010 first powers up, the terminal mode will automatically be selected and a log-in will be requested. If command mode is active, terminal mode can be selected by pressing the ESC key twice in succession. This will cause the 4010 screen to appear on the remote terminal.

Command Mode

If a protocol is enabled, the 4010 serial port automatically switches to command mode any time a start of command character is received (an "@", for the ML protocol). The port remains in command mode until terminal mode is selected or the

Prerequisites

In order to communicate with the Model 4010 remotely, the following equipment will be needed:

- A computer with at least one serial RS-232 port capable of running terminal emulation software. For a remote telephone connection, an internal or external Hayes compatible modem will also be necessary.
- For terminal mode communications, a terminal emulation program capable of emulating ANSI terminals and supporting the Zmodem file transfer protocol. Procomm for DOS, a widely available terminal emulation program, will be used in the following descriptions, however other products are equally applicable.
- If the unit is to be accessed via telephone lines, two modems will be necessary: one for the computer and one for the Model 4010. A Hayes compatible external modem is recommended for the Model 4010. The baud rate should be at least 2400, however 9600 baud or greater is highly recommended. The modem must be capable of retaining setup information, either by saving to non-volatile memory or by setting DIP switches.

- An RS-232 cable will be needed to connect the Model 4010 to the computer or modem. The type of cable used will depend on whether a computer or modem is to be attached. Since the Model 4010's COM1 and COM2 connectors adhere to the 9 pin standards established for personal computers, both types of cables are readily available. Tables 4-6 and 4-7 list wiring connections for these cables.
- For direct computer connection, a null modem cable will be needed. The Model 4010 end of the cable must have a 9 pin female connector. The computer end should be either a 9 pin or 25 pin female connector, depending on the computer's connector type. An ordinary 9 pin female to 25 pin male modem serial cable will be needed for a modem connection.

Configuring the Modem

Before connecting the Model 4010 to a modem, the modem must be configured to answer the phone and act as a "dumb" modem. If the modem has DIP switches, this can usually be done by setting the switches appropriately. Many of the newer modems, however, have no switches, but must be set up via software. This can be accomplished by attaching the modem to a PC or terminal and entering the instruction codes as described below. Once the settings have been entered, they must be saved to the modem's non-volatile memory. Following is a brief description of the commands that should be entered in order to configure a Hayes compatible modem for proper auto-answer operation with the Model 4010.

AT&C1 *Enable Carrier Detect:* The carrier detect line is used to inform the Model 4010 when a carrier tone is detected.

AT&S1 *Enable DSR Control:* When DSR is enabled, the DSR line will be controlled by the modem. DSR will be low when the modem is in command mode and high when the modem is on-line. When this line is dropped, the Model 4010 automatically terminates the remote session. When it is brought high, the Model 4010 presents a log-in message.

AT&D3 *Disconnect when DTR Drops:* When a remote communications session is terminated or times out, the Model 4010 will drop the DTR line. This modem command instructs the modem to disconnect and reset itself when DTR is dropped.

ATA Auto-Answer: This command causes the modem to go off-hook and answer when the phone rings.

ATE0 Disable Command Echo: This prevents command characters from being echoed.

ATQ1 Disable Result Codes: This prevents command result codes (e.g. "OK" when a command is accepted) from being sent to the Model 4010.

AT&W0 *Save Configuration:* Saves the settings to non-volatile memory. NOTE: Though most modems support this command, not all modems contain non-volatile memory. If the modem does not have non-volatile memory, all settings will revert to factory defaults when the modem is reset or power fails.

Though these are the most important commands for an auto-answer application, there are many other options available for special situations. The modem's instruction manual should be referred to for more detailed information.

Setting Up the Com Ports

The Model 4010 can be configured for remote communications by selecting "Port Setup" under the "Comm" menu and then selecting either Com1 or Com2. After a com port is selected, the screen shown in Figure 7-1 will appear.

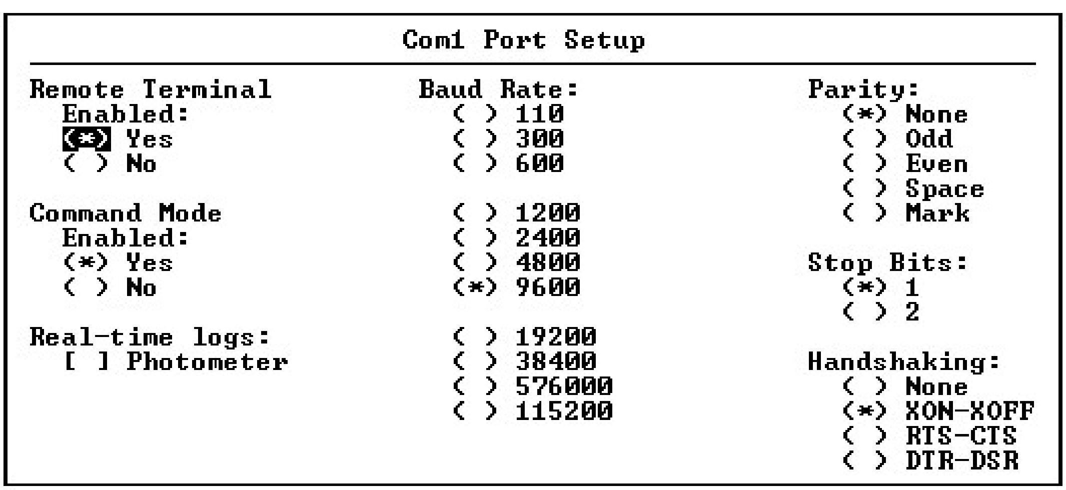


Figure 7-1 Port Set-up Screen

The following options are available from this screen:

Remote Terminal Enabled This option must be set to yes to enable remote terminal mode.

Command Mode Enabled his option must be set to yes to enable command mode.

--- NOTE ---

Although most settings in this screen (e.g. baud rate, etc.) are implemented when the screen is saved, the Model 4010 program must be re-started before changes to the Remote Terminal Enabled or Command Mode Enabled options will be implemented. The system can be re-started by selecting "Restart Program" from the "System" menu.

Real-Time Logs If the photometer option is installed, checking this box will enable a log of data relevant to the photometer's ozone measurements to be transmitted from the serial port.

Baud Rate The baud rate must be set to a value that matches the baud rate of the remote computer. Normally, the higher the baud rate, the better, however if communications errors appear frequently, the baud rate should be lowered.

Parity, Stop Bits, Etc. Except for special applications, these items should be left at their default values of no parity and one stop bit. Data bits are fixed at 8. These are also the defaults for most communications devices and terminal emulation programs.

Handshaking This selects the type of handshaking to use for flow control. XON-XOFF is a software protocol, while RTS-CTS and DTR-DSR are hardware protocols which use RS-232 control lines. For most applications, XON-XOFF is the best choice since it is hardware independent.

Setting Up the Remote Terminal

The following terminal mode options can be changed by selecting "Remote Terminal" under the "Comm" menu (Figure 7-2):

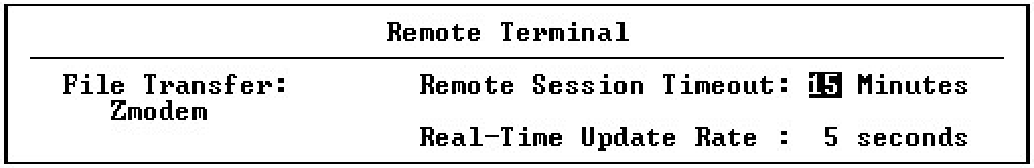


Figure 7-2 Remote Terminal Setup Screen

Remote Session Time-out This selects the time period that the Model 4010 allows after the last keyboard activity before terminating the remote session and disconnecting. When the session is terminated, the DTR line will be dropped, causing an attached modem to disconnect (that is, if it is set up to handle DTR in this way, as described earlier).

Real-Time Update Rate Some screens, such as the status screen and diagnostic screens, update the real-time data at a one second rate on the front panel, however this may be too frequent for remote operation at lower baud rates. This option allows the time between screen refreshes to the remote terminal to be increased, without affecting the update rate on the front panel.

Setting Up the Command Protocol

If the remote command mode is used, the following command mode options may be changed by selecting "Command Mode" under the "Comm" menu (Figure 7-3):

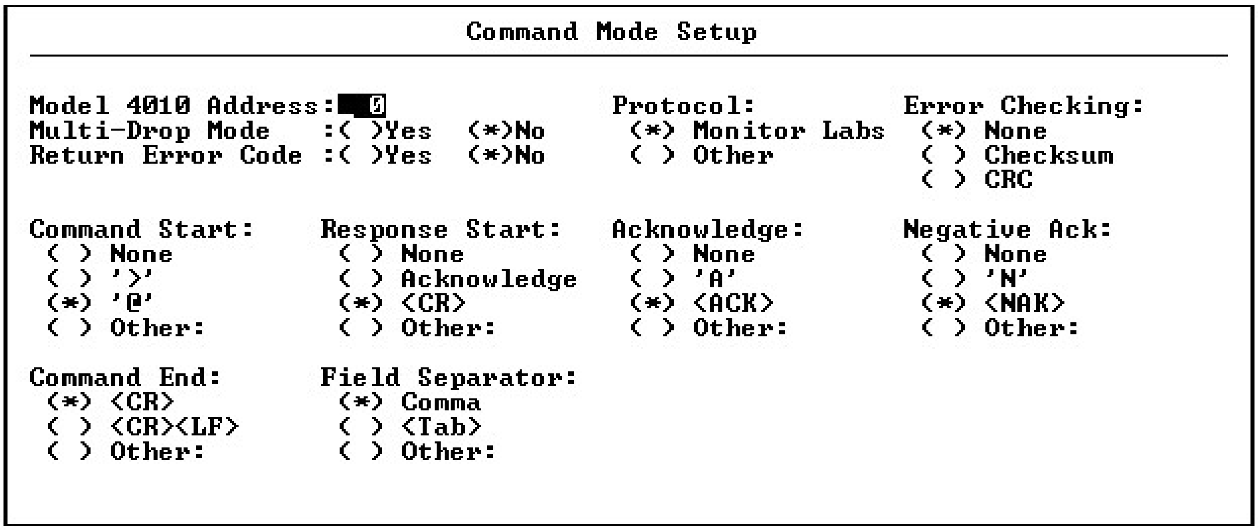


Figure 7-3 Command Mode Setup Screen

The Command Mode screen allows the protocol to be customized to a certain extent. Following are descriptions of the items found on this screen:

Model 4010 Address — The calibrator address must be assigned a value between 0 and 255. The calibrator will only respond to protocol commands if the address in the command matches the address entered here. When muti-drop is disabled, the address field will be ignored, though it must still be present in the protocol.

Multi-drop Mode

Though the 4010’s serial RS-232 ports do not normally support multi-drop operation, with external hardware, they can be made to enable the transmitter only when a command with the 4010’s address is recognized. If multi-drop mode is selected, the 4010 will activate the DTR line when responding to a command with the proper address. This, in turn, would activate a solid-state relay that connects the 4010’s transmit line. Normally, the DTR line will remain low, leaving the transmitter disconnected.

Return Error Code

Though not a standard part of the ML protocol, if error codes are enabled, they can provide an invaluable diagnostic tool for troubleshooting communications problems. When enabled, a two digit numeric code, terminated by a <CR> character, will follow the <NAK>. A listing of possible error codes is provided on page 23.

Protocol

Currently, only one command protocol (the Monitor Labs protocol) is supported by the Model 4010, however others may be supported in the future. If Monitor Labs is selected, all other options will be pre-set to the standard settings for the ML protocol.

Error Checking

If the ML protocol is selected, no data verification will be selected by default, however it is possible to select data verification for the ML protocol, even though it is not a standard feature of the protocol. The section entitled "Data Verification Field" on page 7-22 provides more detail on these data verification methods.

Command Start

The start-of-command character. The "@" symbol is the default for the ML protocol.

Response Start	The character that initiates a response when data is returned. The <CR> character is the default for the ML protocol.
Acknowledge	The response character that acknowledges the execution of a command when no data is returned. The <ACK> character is the default for the ML protocol.
Negative Acknowledge	The response character that indicates that there was a problem responding to the command. The <NAK> character is the default for the ML protocol.
Command End	The end-of-command character. The <CR> character is the default for the ML protocol.
Field separator	The character used to separate parameter or data fields in commands and responses. The comma character is the default for the ML protocol.

Configuring the Computer for Terminal Mode

The computer's terminal emulation program must be configured before a successful remote connection can be made. Following are several considerations and descriptions of how to set up each item in Procomm for DOS. For more details, refer to the terminal program's documentation.

The following items can be configured in Procomm for DOS by entering the Line/Port Setup screen with the ALT-P command:

Comm Port	Select the comm port (usually COM1 or COM2) to which the Model 4010 or modem is attached.

--- NOTE ---

A frequent source of problems when setting up communications links on IBM compatible PC's are conflicts with the mouse and internal modem ports. Also, though some computers support COM3 and COM4, these ports usually share interrupts with COM1 and COM2, respectively. This can cause conflicts when COM1 and COM3 or COM2 and COM4 are used simultaneously.

Baud Rate

The baud rate must be set to a value that matches the baud rate of the Model 4010 and is within the capability of the computer. Normally, the higher the baud rate, the better, however if communications errors appear frequently, the baud rate should be lowered.

Parity, Data & Stop Bits

Except for special applications, these parameters should be left at their default values (no parity, 8 data bits and one stop bit). These are also the defaults for the Model 4010.

In addition, the following items should be confirmed or set-up.

Terminal Emulation

This should be set to ANSI. In Procomm, ANSI is the default, but it can be confirmed by selecting "Terminal Options" from the ALT-S menu.

Disable Status Line

Many terminal emulation programs, including Procomm for DOS, use the bottom line on the screen to present status information. Since the Model 4010 presents information on all 25 lines of the screen, the terminal program's status line should be disabled. In Procomm, this is accomplished by selecting "Display/Sound Options" from the ALT-S menu.

Operating the Model 4010 Remotely using Terminal Mode

Once the Model 4010 and all modems, computers and cables are configured correctly, it is simple matter to establish a communications link and operate the Model 4010 remotely. The Model 4010 can sense that a communications link is active by monitoring the DSR line. When a connection is sensed (e.g. when the modem answers the phone or a cable is attached), the Model 4010 will present the following log-in message:

```
Sabio Model 4010 Dilution Calibrator Remote Access

Press any key to continue ...
```

Simply pressing a key will log into the Model 4010 and an exact image of the Model 4010's front panel display will be presented on the remote computer's screen. Subsequently pressing keys, either on the front panel or at the remote computer, will cause both screens to respond accordingly.

If command mode is enabled and a command is sent, the 4010 automatically switches to command mode. Pressing the ESC key will return the 4010 to terminal mode.

Most keys on the remote computer's keyboard correspond to equivalent keys on the Model 4010's front panel, however there are a few exceptions, which are listed below.

Table 7-1 PC Keyboard Model 4010 Key Mapping

Model 4010 Front Panel	PC Keyboard	Function
F2	Shift-TAB	Go to the previous field.
F3	TAB	Go to the next field.
F4	PgUp	Go to the previous page.
F5	PgDn	Go to the next page.
F6	ALT-V	Toggle voltage/eng. units.
F7	ALT-U	Change units.
Standby	Home	Go to the top menu bar.
Status	F8	Display the status screen.

Audit	F9	Display the Run Sequence menu.
Set-up	F10	Display the Sequence menu.
Diag	F11	Display the Diag menu.
Report	F12	Print the Model 4010 screen.
End Seq.	ESC	Back up one menu level.
Purge	!	Purge the inlet.
ALT	---	Toggles ALT mode.

Note: that the ALT key on the front panel has a different function from the computer's ALT key. The Model 4010's ALT key enables or disables the ALT mode, which allows shifted characters to be accessed. The ALT key on the PC keyboard alters the meaning of another key held down simultaneously, but does not toggle the Model 4010's ALT mode.

Updating the Operating Program

The Model 4010's operating program and configurations can be updated remotely by using the Zmodem file transfer protocol. Any time a user is logged in to a Model 4010 remotely, a Zmodem file can be sent or "downloaded". The Model 4010 automatically recognizes that a file transfer is coming and receives the file. While the file is being received, a file transfer status screen will be presented on the Model 4010's front panel (but not on the remote terminal's screen), indicating the transfer's progress (See Figure 7-4).

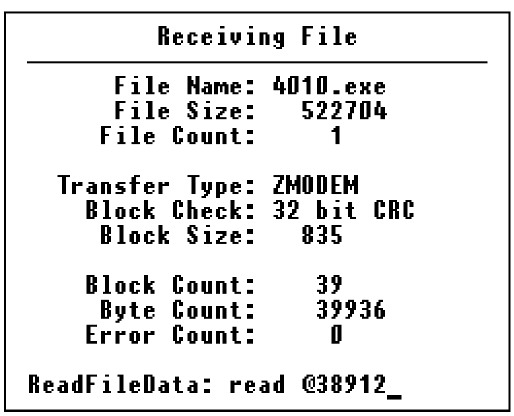


Figure 7-4 File Transfer Status Screen

The non-volatile flash memory in the Model 4010 is configured to appear to the system as hard disk drive C. There are two main sub-directories in drive C, C:\4010 and C:\CONFIG, which contain the operating programs and user configurations, respectively. A third directory, C:\DOWNLOAD, receives downloaded files where they remain until the system is re-started. When the Model 4010 is re-started these files are transferred to their appropriate directories, after which the C:\DOWNLOAD directory should be empty.

Following is a description of the program and configuration files that may be downloaded to the Model 4010:

c:\4010 directory:

4010.exe — This is the main operating program.

4010msg.cfg — The compiled message file that contains the Model 4010's screen text.

--- CAUTION ---

The 4010msg.cfg and 4010.exe files must be of the same version. If a mismatch occurs, an error message will be presented and the Model 4010 program will not start.

4010def.cfg — The factory default file.

4010gas.cfg — The default gas file.

4010gas.idx — The default gas file's index file.

4010init.exe — Initializes the Model 4010 hardware.

4010logo.exe — Presents the Model 4010 logo screen.

4010boot.bat & 4010file.bat — These batch files work together to move downloaded information to their appropriate directories and start the Model 4010 program.

c:\config directory:

--- NOTE ---

Most of the following configuration files (*.cfg) have an index file (*.idx) associated with them. These two files should be kept together.

If any of the *.cfg files are not present, either an empty file or a default file will be created along with their associated index files.

dynparms.cfg Contains the system parameters, device parameters and device calibration data. When dynparms.cfg is not present, a new file will be created and the factory defaults will be copied from c:\4010\4010def.cfg.

gas.cfg Contains the gas table. When gas.cfg is not present, a new file will be created and the default gas table will be copied from c:\4010\4010gas.cfg.

gasstd.cfg Contains information about the gas standards.

pasgn.cfg Contains port assignment information.

seq.cfg Contains information about sequences and points.

permdev.cfg Contains information about permeation devices.

poven.cfg Describes the permeation oven contents.

The following procedure describes how to update the Model 4010's operating software using Procomm for DOS:

--- NOTE ---

Before downloading software, all Model 4010 configuration and calibration information should be recorded. If something goes wrong during the download procedure, it may be necessary to re-enter some of this information.

[1] Connect to and log into the Model 4010 as described in the previous sections.

[2] Press the PgUp key on the PC's keyboard. Select Zmodem from the pop-up window that lists file transfer protocols.

[3] A "Send Zmodem" window will pop up, prompting for a file name. Enter the path and file name. If more than one file is to be sent, wild cards can be used.

Examples:

a:\4010\4010.exe	Sends the main Model 4010 program.
a:\config\seq.*	Sends the seq.cfg and seq.idx files
a:\4010\4010*.*	Sends all Model 4010 program files.

[4] A Procomm transfer status window will pop up displaying the progress of the file transfer. A similar screen will pop up on the Model 4010's front panel.

[5] When the transfer is finished, Procomm will beep and flash "COMPLETED" in the transfer status window. The Model 4010 will display the message "*** File Transfer Successful ***" on both screens. Press escape to close the Model 4010's transfer status window.

[6] Restart the Model 4010 by selecting "Restart Program" from the "System" menu. The remote terminal session will log off and the Model 4010 will re-start. On the Model 4010's front panel, the message "New files have been downloaded; Updating ..." will be presented, after which the downloaded files will be copied to their appropriate directories.

When the main Model 4010 program starts, it automatically checks for conflicts between file versions. If conflicts are discovered, error messages will be displayed. In the case of configuration file conflicts, an option to create a new, empty file will be given. If there are no conflicts, the Model 4010 program will start and new program and/or configuration files will be in effect.

--- CAUTION ---

Since the communications link is terminated during the restart process, start-up error messages are only presented on the Model 4010's front panel. Care should be taken to assure version compatibility before downloading files from a remote location.

Disconnecting

A remote communications session should normally be terminated or "logged out" by selecting the "Disconnect" option under the "Comm" menu. In addition, the Model 4010 will automatically log out if any of the following situations occur:

- If a modem is connected, and carrier is lost.
- If the RS-232 cable is disconnected.
- If there is no keyboard activity for the Remote Session Time-out period.

Operating the Model 4010 Remotely using Command Mode

The Model 4010 currently supports the protocol used by Monitor Labs, Inc. for interconnecting their line of air quality analyzers. This section describes this protocol in detail and presents descriptions of the commands available for remote interaction with the Model 4010. Within this section, the following conventions are used within command descriptions.

X	A single letter represents an ASCII character.
XXX	Fields with all capital letters indicate fixed length fields.
{ }	Curly brackets surround variable-length fields.
[ ]	Square brackets surround optional fields.
< >	Items enclosed by less/greater than brackets are non-printable characters.
,	The comma is an ASCII comma character.

Spaces found within commands are not a part of the protocol.

The Monitor Labs Protocol

The Monitor Labs protocol is designed for interconnecting the Monitor Labs line of air quality analyzers in a multi-drop RS232 network. This protocol does not normally support error checking, however a data verification field will be appended to the end of commands and responses if one of the data verification methods is selected when setting up the command mode options.

Fields in ML commands and responses can vary in length, making a field separator necessary. By default, the comma character (2C hex) is used as a field separator to indicate the end of one field and the beginning of the next.

Number Representation (Floating Point)

The Monitor Labs protocol represents all numeric values as floating point (or integer) ASCII numbers with the most significant digit transmitted first. The number can include a decimal point and sign and can be presented in scientific notation, will an E+xx immediately following the number (with no space), where xx is the exponent and + is the sign (positive or negative). Following are examples of legal numeric values:

1	123.456
123456	+1.23456
-1.23456	-1.23456E+02

Numbers representing analog or calculated values will be presented in the default engineering units, regardless of what units are currently being displayed on the 4010’s screen at the time.

Digital Word Representation

The group commands that accept or return groups of digital data in the Monitor Labs protocol represent the state of each digital I/O bit as an ASCII one or zero, where a one indicates and on or active condition.

In the Model 4010, there are two digital I/O groups, the Control Outputs (that activate solenoid valves, etc.) and the User I/O. Each group consists of 24 digital I/O bits and is represented by 24 ASCII 0s or 1s. Within each group of bits, the lowest numbered I/O point is transmitted first as shown in the example, below:

```
       Bit#:  1      8 9     16 17    24
       Data:  11000101 11101010 00100100
ASCII Value:  110001011110101000100100
```

Command Str*u*cture

Each ML command begins with a start of command character (the "@" symbol) followed by a command, an address, an optional data field and terminated by a carriage return. If there is data, it will be presented as parameter fields separated by commas. All characters except the terminating carriage return must be printable ASCII characters. One exception are optional <STX> and <ETX> characters (not shown), which are ignored, but allowed for the sake of compatibility.

Command Structure

@ {cmd}, {addr}, [{param1},] • • • [{param1},] [CHK] <CR>

Where:

,	= Comma (field separator)
@	= Start of Command (40 hex)
{Cmd}	= Command Character
{Addr}	= Address
{ParamX}	= Parameters (optional)
[CHK]	= Optional Data Verification Field
<CR>	= Carriage Return Character (0D hex)

Starting and Ending Commands

An ML command is started by sending an "@" (40 hex) character and terminated by a carriage return (0D hex). The Monitor Labs protocol calls for an optional <STX> character (02 hex) as a start of command and <ETX> character (03 hex) as an end of command character. These characters may be included, but will be ignored by the 4010.

Command Words

Command words are one or more characters in length. Any combination of printable letters, numbers or symbols (except the start-of-command character, "@") may be used in commands. Command words are not case sensitive.

Calibrator Address

Following the command word is an address, up to three digits in length, with the most significant hex digit transmitted first. This is the decimal address of the calibrator.

If the calibrator does not recognize its unique address, the remainder of the command will be ignored and no response will be returned. The addressed instrument will always respond, either with an acknowledgment, with data or with a negative acknowledgment if there is an error of some sort.

Data Fields

Some commands have data associated with them. If so, the data will be returned in one or more fields, separated by commas. The number of parameters will vary from one command to another, but will always be the same for a particular command. The length of each parameter may vary depending upon the data; for example, how large a numeric value is. The exact meaning of data in the data field depends entirely upon the command. The data must consist of printable ASCII characters and cannot include the start-of-command character (the "@" symbol, by default).

Data Verification Field

The standard Monitor Labs protocol does not support error checking, however by selecting one of the two data verification methods supported by the 4010, error checking can be added to both commands and responses.

The data verification field consists of between two and four characters, depending upon the data verification method selected. The data verification field is used to verify the integrity of the received data.

When data verification is enabled, it can be bypassed for individual commands by replacing the characters with "?" characters (3F hex). This can be useful for testing purposes.

The calibrator always calculates and returns a checksum in its response, even if the command checksum is replaced by "?" characters.

Following are descriptions of the two data verification methods available. More details regarding the calculation of these methods, along with C source code, can be found in the *Mistic Protocol User's Guide,* a document published by Opto 22. This document can be downloaded from Opto 22's web site on the Internet at http://www.opto22.com.

Two Byte Hex Checksum

The checksum is calculated by summing the decimal values of all preceding ASCII characters in the command, excluding the "@" start of command character. The sum is then divided by 256 and the integer remainder is converted to two hex digits.

For example:

@P,0010D<cr>

is a valid command to activate a purge cycle. The checksum (0D hex) is calculated as follows:

ASCII characters:	P , 0 0 1
Value of characters:	80 + 44 + 48 + 48 + 49 = 269

Where 269/256 = 1 with a remainder of 13 (0D hex).

Four Byte Hex CRC

The checksum method of data verification is simple to implement, however it is possible for data to be altered without affecting the checksum; for example if there are two complementary errors in the data.

The cyclical redundancy check, or CRC, provides a more secure form of error checking. If the CRC method of data verification is chosen, the Model 4010 will calculate a 16 bit CRC using the CCITT method, which uses the following polynomial:

$$X^{16} + X^{12} + X^{5} + 1$$

(With a starting value set to 0).

Response Structure

Any time a command is sent with an address recognized by an instrument on the network, the addressed instrument should return a response. The exact response will depend upon whether the command is to return data or not and if errors are detected in the command. Following, the three possible responses are summarized:

Successful Response, no data:

<ACK>

Where: <ACK> = Acknowledge Character (06 hex)

Successful Response, with data:

<CR> {data1}, [{data2},] • • • [{dataN},] [CHK] <CR>

Where:	,	= Comma (field separator)
	{dataX}	= Data Field
	[CHK]	= Optional Data Verification Field
	<CR>	= Carriage Return Character (0D hex)

Error Response

<NAK>[ER][<CR>]

Where:	<NAK>	= Negative Acknowledge Character (15 hex)
	[ER]	= Optional two digit error code
	[<CR>]	= Optional carriage return character

If no errors are detected and no data is to be returned, an <ACK> (06 hex) character will be returned to indicate that the command was successfully executed. If data is needed in the response, a <CR> (0D hex) character will be returned followed by one or more parameters of data, separated by commas. A final comma separates the last data item from the carriage return (or optional data verification field) at the end of the response. As with command data fields, all response data characters must be printable ASCII characters.

Should there be a problem with the command, a <NAK> (15 hex) character will be returned, optionally followed by an error code. A listing of possible error codes is provided on page 23.

If no response is received for a certain time period, the master program should time-out and the command should either be aborted or re-sent (for a limited number of re-tries).

Commands

The following pages list the commands available to the Model 4010 and their implementation. Following the command list, a description of each command is presented with the formats of the command.

Following is a glossary of common abbreviations, symbols and fields that may be found within the command descriptions. Other, more specialized fields are described within the command descriptions:

Monitor Labs Commands

		Hex	Decimal
@	Start of Command Character	40	64
,	Comma (field separator)	2C	44
<ACK>	Acknowledge	06	06
<NAK>	Negative Acknowledge	15	21
<CR>	Carriage Return Character	0D	13
{Cmd}	Command Word		
{Addr}	Address		
CHK	Checksum (2 or 4 byte hex)		
ER	Error code (2 bytes)		

Common Data and Parameter Fields for Commands

{seq name}	The name of a calibration sequence. It is not necessary to spell out the entire sequence name; the first few characters will suffice as long as they are unique. If more than one sequence starts with the characters in the {seq name} field, an error will be returned.

{point}	A sequence point. This can be a number between 1 and 20. If the field is empty, either the first or next point will be selected, depending upon the context.

Command Summary

Description	Page #	Command
Stop	23	S
Purge	24	P
Timed Sequence	25	TS {seq name},{point}
Manual Sequence	26	MS {seq name},{point}
Get Status	27	GS {status types}

Error Codes

If error responses are enabled, the Model 4010 may return the following error response codes:

01	Undefined Command	The command was not recognized.
02	Check Sum Error	The checksum calculated by the 4010 did not match the checksum in the command.
03	Buffer Overrun Error	The calibrator's receive buffer was overrun because the command packet was too long.
05	Data Field Error	The wrong number of characters were received.
07	Data Error	There was an illegal value in a command parameter field.
12	Timeout Error	The end of command character (<CR>) was not received within the timeout period.
51	Cmd Too Long	The command field was too long.

52	Addr Too Long	The address field was too long.
53	Resp Buff Overrun	The response data buffer was overrun.
54	Response Error	There was an error calculating a response data field.
70	Seq Start Error	An error occurred attempting to start the seq.
71	Bad Seq Name	The sequence name is invalid.
72	Bad Seq Point	Invalid point number.
73	No Active Seq	No sequence is active.

Stop (S)

The Stop command terminates any calibrations in progress and places the calibrator in a quiescent, idle state.

Command Format

Command

@ S , {AAA} [CHK]<CR>

Response

Good: <ACK>
Error: <NAK>[ER][<CR>]

Purge (P)

The Purge command causes the calibrator to purge its source inlet manifold for a short duration. The default duration is five seconds, but can be changed in the 4010's dilution parameters setup screen. If a source valve is active when the purge command is sent, the 4010 will purge calibration gas through the manifold; otherwise, the gas manifold will simply be opened to atmosphere for the purge duration.

Command Format

Command

@ P , {AAA} [CHK]<CR>

Response

Good: <ACK>
Error: <NAK>[ER][<CR>]

Timed Sequence (TS)

This command causes a timed sequence to be initiated. The sequence to be started is identified by the {seq name} field, which is the ASCII sequence name.

The point at which to start the sequence can optionally be entered in the {point} field. If no point is entered, the sequence will start at the first or last point, depending upon whether the sequence order is ascending or descending.

A more detailed description of the usage of the {seq name} and {point} fields can be found on page 25.

Command Format

Command

@ TS , {AAA} , {seq name} , {point} , [CHK] <CR>

Where:

{seq name}	=	The name of the sequence.
{point}	=	The starting point. If blank, the sequence starts at the beginning.

Response

Good: <ACK>
Error: <NAK>[ER][<CR>]

Comments:

Leaving the {seq name} and/or {point} blank will have the following results:

@ TS , {AAA} , {seq name} , [CHK]<CR>

If a sequence is already active with the same name as {seq name}, the sequence will be re-started beginning with the first point (or last point if the sequence order is descending). If no sequence is active or the sequence is different, the new sequence will be started, beginning with the first (or last) point.

`@ TS , {AAA} , ,{point} , [CHK]<CR>`

If a sequence is already active, the new point in the same sequence will be activated and the timed sequence will continue from that point. If no sequence is active, the command will be ignored.

`@ TS , {AAA} [CHK]<CR>`

If a sequence is already active, the sequence will advance to the next point and the timed sequence will continue from that point (if it is the last point, the sequence will be terminated). If no sequence is active, the command will be ignored.

Manual Sequence (MS)

This command causes a manual, operator stepped sequence to be activated. The point selected in the {point} field of the sequence identified by {seq name} will be activated and will remain active until another point is activated, calibrations are stopped or a timeout occurs.

If a sequence point is active when the Manual Sequence command is sent, it will be terminated and superceded by the new sequence and/or point. It is not necessary to use the Stop command before sending a Start Point command. A more detailed description of the usage of the {seq name} and {point} fields can be found on page 25.

Command Format

Command

`@ MS , {AAA} , {seq name} , {point}, [CHK]<CR>`

Where:

{seq name}	=	The name of the sequence.
{point}	=	The point number.

Response

Good: <ACK>
Error: <NAK>[ER][<CR>]

Comments:

Leaving the {seq name} and/or {point} blank will have the following results:

@ MS , {AAA} , {seq name} , [CHK]<CR>

If a sequence is already active with the same name as {seq name}, the next point in the sequence will be selected. If no sequence is active or the sequence is different, the first point (or last point if the sequence order is descending) of the new sequence will be started.

@ MS , {AAA} , ,{point} , [CHK]<CR>

If a sequence is already active, the new point in the same sequence will be activated. If no sequence is active, the command will be ignored.

@ MS , {AAA} , [CHK]<CR>

If a sequence is already active, the next point in the sequence will be activated (if it is the last point, the sequence will be terminated). If no sequence is active, the command will be ignored.

Get Status (GS)

The Get Status command returns current status information about the Model 4010. The status generally corresponds to information that is presented on the 4010's status screens. The response will depend on the {status types} field, which is a list of from one to five characters that select the categories of status information that should be returned. The following four status selection characters may be used in the {status type} field to request status information from the 4010:

D - *Dilution Status*: Returns the flow rates of the diluent, ozone and source mass flow controllers and the states of the dilution unit solenoid valves.

O - *Ozone Status:* Returns status information pertaining to the ozone generator, if it is installed.

P - *Photometer Status:* Returns status information pertaining to the photometer, if it is installed.

V - *Perm Oven Status:* Returns status information pertaining to the perm oven, if it is installed.

G - *Gas Concentration Status:* Returns the total dilution flow rate and the names and concentrations of all gases being produced.

The status selection characters can be strung together in the {status types} field in any order. The respective categories of data will be returned in the order in which these characters appear in the command. If a category of status information is requested that pertains to an option that has not been enabled, that information will be omitted from the returned data.

The status information is always presented in pre-determined engineering units. The following units of measure are used for all returned status data:

Flows	Standard Cubic Centimeters Per Minute (SCCM).
Temperatures	Degrees Centigrade (°C).
Pressures	Millimeters of Mercury (mmHg).
Gas Concentrations	Parts Per Billion (PPB).

Command Format

Command

`@ GS , {AAA}, {status types}, [CHK]<CR>`

Where:

{status types} = Characters indicating what types of status should be returned.

Responses

Good Response Examples:

{status type} = D - Dilution Status

`<CR> {dilution status}, [CHK]<CR>`

{status type} = O - Ozone Status

`<CR> {ozone status}, [CHK]<CR>`

{status type} = P – Photometer Status

<CR> {photo status}, [CHK]<CR>

{status type} = V - Perm Oven Status (with perm oven enabled)

<CR> {perm status}, [CHK]<CR>

{status type} = G – Gas Concentration Status

<CR> {gas status}, [CHK]<CR>

{status type} = DO - Mixed Status

<CR> {dilution status}, {ozone status}, [CHK]<CR>

{status type} = DOPG – Mixed Status

<CR> {dilution status}, {ozone status}, {photo status},
{gas status}, [CHK]<CR>

{status type} = GDO - Mixed Status

<CR> {gas status}, {dilution status}, {ozone status}, [CHK]<CR>

Where:

{dilution status} = {dil mfc ctl}, {dil mfc mon}, {o3 mfc ctl},
{o3 mfc mon}, {src mfc #}, {src mfc ctl},
{src mfc mon},{sys temp},
DDDDDDDDDD, SSSSSS

{ozone status} = {o3 temp ctl}, {o3 temp mon}, {o3 lamp ctl},
{o3 lamp curr}, {o3 lamp int}, {o3 conc ctl},
{o3 conc mon}

{perm status} = {perm mfc ctl}, {perm mfc mon},
{perm temp ctl}, {perm temp mon}, MMMM

{photo status} = {photo avg}, {lamp temp ctl},
{lamp temp mon}, {lamp curr ctl},
{lamp curr mon}, {lamp intensity},
{det samp}, {det ref},
{gas temp}, {gas pres}, {gas flow}, PPP

{gas status} = {total flow mon}, {num gases},
{prim gas name}, {prim gas conc},
{gas 2 name}, {gas 2 conc},
• • • ,
{gas N name}, {gas N conc}

And Where:

<u>Dilution Data Fields</u>

{dil mfc ctl} = The diluent MFC setpoint (SCCM)

{dil mfc mon} = The measured diluent MFC flow (SCCM)

{o3 mfc ctl}	=	The ozone MFC setpoint (SCCM)
{o3 mfc mon}	=	The measured ozone MFC flow (SCCM)
{src mfc #}	=	The source MFC number (1 or 2)
{src mfc ctl}	=	The source MFC setpoint (SCCM)
{src mfc mon}	=	The measured source MFC flow (SCCM)
{sys temp}	=	The system temperature
DDDDDDDDDD	=	The states of the dilution unit solenoid valves. Each character is a 0 or 1, where 1 indicates that the valve is on. From left to right, these bits correspond to the following solenoid valves: Diluent 1 Valve Diluent 2 Valve Source 1 Valve Source 2 Valve Source 3 Valve Source 4 Valve Source 5 Valve Source 6 Valve Purge Valve Output Valve
SSSSSS	=	The states of the instument solenoids. Each character is a 0 or 1, where 1 indicates that the corresponding instrument solenoid output is active.

Ozone Data Fields

{o3 temp ctl}	=	The ozone lamp temperature setpoint (°C)
{o3 temp mon}	=	The measured ozone lamp temperature (°C)
{o3 lamp ctl}	=	The ozone lamp intensity setpoint (V)
{o3 lamp curr}	=	The ozone lamp current (no units)
{o3 lamp int}	=	The measured ozone lamp intensity (no units)
{o3 conc ctl}	=	The ozone concentration setpoint (PPB)
{o3 conc mon}	=	The calculated ozone concentration (PPB)

Photometer Data Fields

{photo avg}	=	The averaged ozone measurement (PPB)
{lamp temp ctl}	=	The photometer lamp temperature setpoint (°C)
{lamp temp mon}	=	The measured photometer lamp temperature (°C)
{lamp curr ctl}	=	The photometer lamp intensity setpoint (V)
{lamp curr mon}	=	The photometer lamp current (no units)
{lamp intensity}	=	The photometer lamp intensity (no units)
{det samp}	=	The photometer detector – sample (no units)
{det ref}	=	The photometer detector – reference (no units)
{gas temp}	=	The sample gas temperature (°C)
{gas pres}	=	The sample gas pressure (mmHg)
{gas flow}	=	The sample gas flow (SCCM)

PPP	=	The states of the photometer pump and solenoid valves. From left to right, these bits correspond to the following solenoid valves: Photometer Pump Photometer Reference Valve Photometer Sample Valve

Perm Oven Data Fields

{perm mfc ctl}	=	The perm MFC setpoint (SCCM)
{perm mfc mon}	=	The measured perm MFC flow (SCCM)
{perm temp ctl}	=	The perm oven temperature setpoint (°C)
{perm temp mon}	=	The measured perm oven temperature (°C)
MMMM	=	The states of the perm oven pump and solenoid valves. From left to right, these bits correspond to the following solenoid valves: Perm Vent Valve Perm Source Valve Perm Pump External Perm Valve

Gas Concentration Data Fields

{total flow mon}	=	The measured total flow (SCCM)
{num gases}	=	The number of gases following.
{prim gas name}	=	The primary gas symbol (NO2, H2S, etc.)
{prim gas conc}	=	The primary gas concentration (PPB)
{gas 2 name}	=	The 2nd gas symbol (NO2, H2S, etc.)
{gas 2 conc}	=	The 2nd concentration (PPB)
{gas N name}	=	The Nth gas symbol (NO2, H2S, etc.)
{gas N conc}	=	The Nth concentration (PPB)

Response*:* <NAK>[ER][<CR>]

Section 8 Internal Calibrations

The accuracy of diluted calibration gases produced by the Model 4010 is dependent upon the accuracy of its mass flow controllers and ozone generator. These devices are calibrated at the factory prior to shipment to the customer, but in order to maintain the 4010’s calibration accuracy over time, it is recommended that the mass flow controllers and ozone generator be checked periodically against external calibration standards and calibrated as necessary.

Fortunately, calibrating any of the Model 4010’s flow controllers or the ozone generator is a simple process that may be performed by the end-user. This is usually accomplished by following an interactive software procedure that prompts the user to perform a multi-point calibration, stepping the device through multiple setpoints across its range. For each point, the user is prompted to enter the measured results from the external calibration reference, resulting in a table comparing the 4010’s control and monitor voltages to the external reference. Alternatively, the user may manually enter a calibration table, or simply enter polynomial coefficients, in order to calibrate a device.

Whichever technique is used, it is essential that all devices be calibrated in order to establish the correspondence between the 4010’s control and monitor voltages and the actual flow rate or ozone concentration.

Calibration Data

Two basic types of data may contain the information necessary to calibrate a device: 2nd order polynomial coefficients and/or a lookup table. This data may then be used to produce equations characterizing the device using one of four linearization methods.

Polynomial coefficients are useful for linear or slightly non-linear devices and are the easiest way to calibrate a device if the coefficients are already known. The coefficients a, b and c are used in the following equation to linearize and convert a voltage signal to engineering units:

$$Y = a + bX + cX^2$$

Where:

X = Control or monitor voltage (Volts)
Y = Flow rate or ozone concentration (SCCM or PPB)
a = Intercept
b = Slope
c = Non-linear term

Lookup tables contain more information and allow more linearization options. Each table consists of up to 20 rows, each representing a calibration point, and three columns: the control voltage, the monitor voltage and the actual flow or ozone concentration. The data contained in a lookup table may be used to automatically calculate polynomial coefficients using regression techniques or the table’s data may be used directly for the lookup and spline linearization methods.

Two sets of linearization equations, referred to as the control and monitor equations, are produced from the calibration data. The control equation converts the flow or ozone concentration (in SCCM or PPB, respectively) to a control voltage. The monitor equation converts a monitored voltage to engineering units for displaying flow rates or ozone concentrations. Of the two, the control equations are the most important since they establish the correspondence between a desired flow rate or ozone concentration and the control voltage sent to the device. The monitor equations are only used for scaling measured voltages to engineering units for presentation on the display.

Linearization Methods

There are four linearization methods, independently selectable for each calibrated device. The method to be used for a particular device may be specified in the Device Parameters screen, which can be selected from the device's calibration menu.

The linearization methods available are described below. A graphical comparison of these methods is shown in Figure 8-1.

Linear Fit — This method finds the best straight-line fit to the calibration data. The linear fit is best suited to very linear data.

Polynomial Fit — The polynomial fit, used in previous versions of the software, finds the best 2nd order polynomial fit to the calibration data and can compensate for non-linearity in the data.

Lookup Table — This method uses the lookup table directly and interpolates a straight line between table points. By definition, this technique will reproduce each calibration point exactly (assuming perfect repeatability).

Spline Fit — This method uses a cubic spline to find a smooth curve that passes through all calibration points. As with the lookup table, this technique guarantees that calibration points will be reproduced exactly, but is more likely to accurately reproduce data between calibration points.

If a lookup table has been generated for a device, any of the four methods may be used. For the first two methods, polynomial coefficients will be generated from the data in the lookup table using regression techniques. Once the coefficients are known, they can be entered manually rather than entering an entire data table. The last two linearization methods require that a lookup table be entered, either manually or during an interactive calibration.

The default method used in factory calibrations for mass flow controllers is the polynomial fit. The spline fit is the default method for the ozone generator.

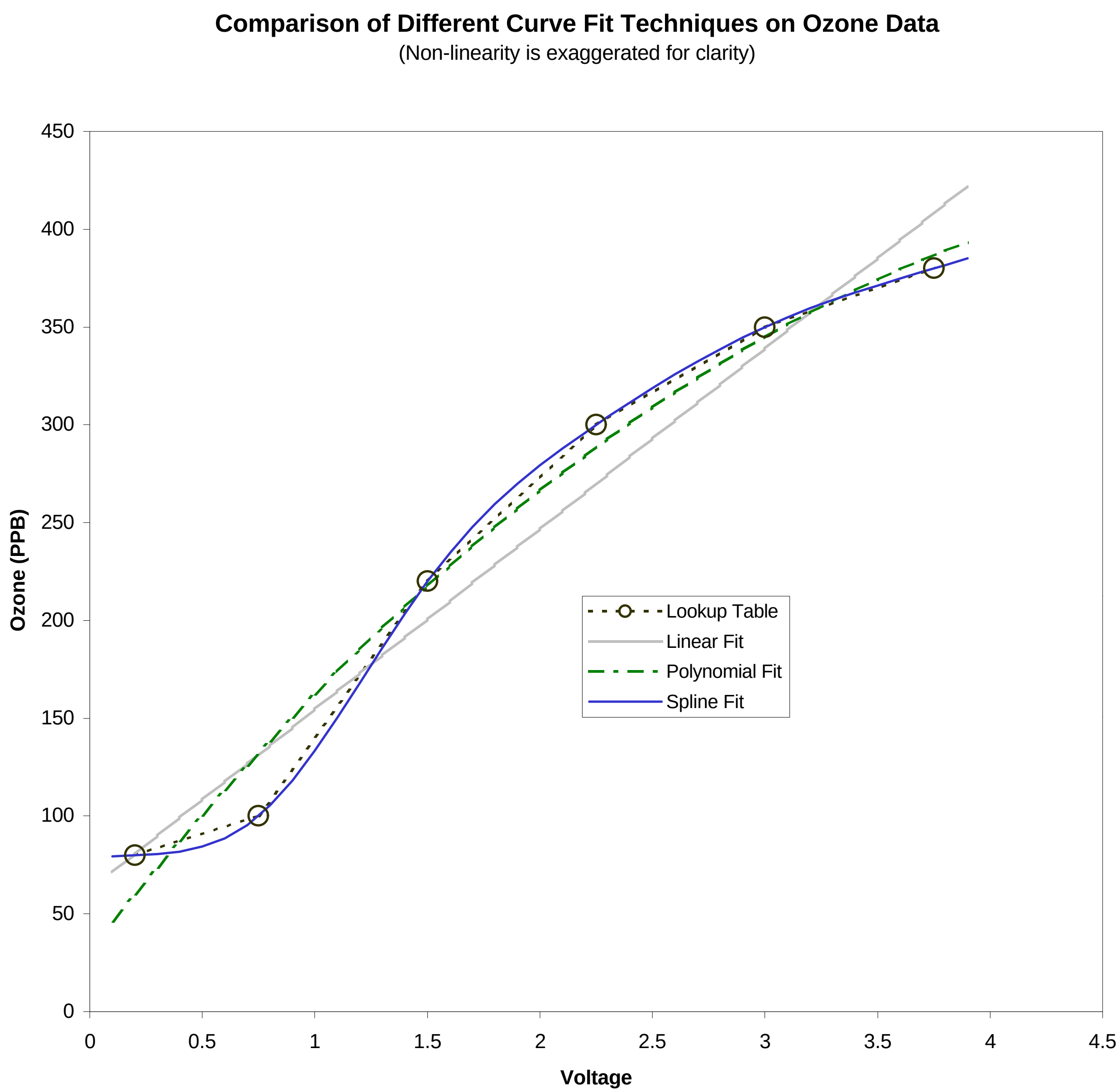


Figure 8-1 Comparison of Linearization Methods

Calibration Menu

For each device that can be calibrated, a selection is available under the Devices menu. Selecting the calibration item for a device pops up its Calibration Menu.

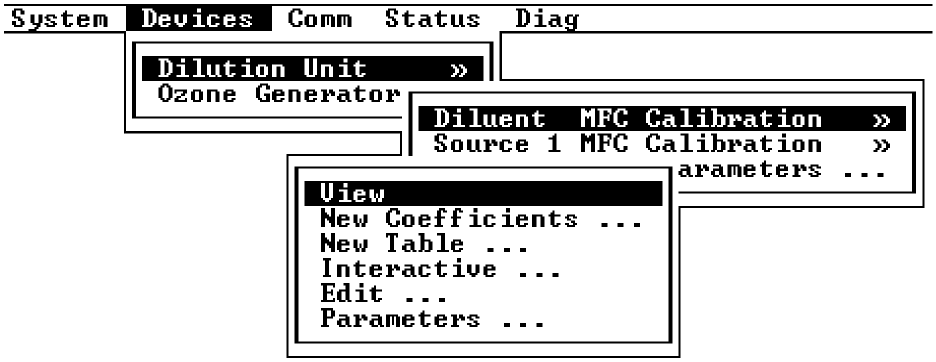


Figure 8-2 Calibration Menu

Viewing Calibration Data

Selecting View from the calibration menu will allow the most recently entered calibration data to be viewed. If the data was entered as coefficients, the coefficients will be displayed; if the data was entered as a table or via the interactive calibration procedure, the lookup table data will be displayed.

Manually Entering Polynomial Coefficients

If polynomial coefficients have previously been calculated for a mass flow controller, they can be entered directly by selecting New Coefficients from the flow controller's calibration menu.

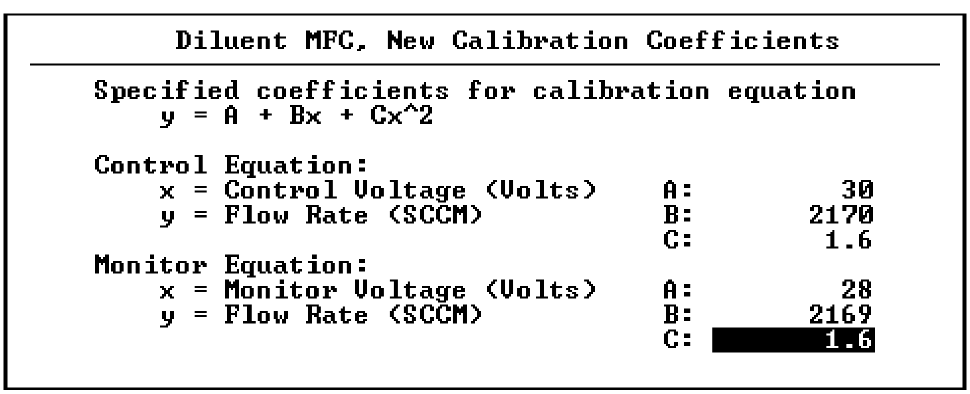


Figure 8-3 New Calibration Coefficients

If the coefficients are not known for a device, for example a mass flow controller, and it is desirable to establish the relationship between voltage and flow rate, relying on the MFC manufacturer's physical calibration, default calibration coefficients can be entered in the New Coefficients screen. Default coefficients are calculated as follows:

a = 0
b = Max Flow / 5
c = 0

Where Max Flow = Full scale flow of the MFC in SCCM

Note that, although the 4010 allows the units of measure to be selected in most screens, all calibration coefficients are based on units of SCCM for flows and PPB for ozone.

Manually Entering a Calibration Table

Selecting New Table from the calibration menu allows data from a previous calibration to be re-entered without the need for an interactive calibration. Also, if a new mass flow controller is installed in the 4010, a calibration table based on the MFC manufacturer's data may be entered by selecting the New Table option from the calibration menu.

Diluent MFC, New Calibration Table

Point	Control (V)	Monitor (V)	Flow (SLPM)	Point	Control (V)	Monitor (V)	Flow (SLPM)
1	0.500	0.501	1.1131	11			
2	1.000	1.001	2.2105	12			
3	1.250	1.251	2.7382	13			
4	2.500	2.502	5.4655	14			
5	3.750	3.752	8.1900	15			
6	5.000	5.003	10.9200	16			
7				17			
8				18			
9				19			
10				20			

Control Equation	A:	30	Monitor Equation	A:	28
x: Control V	B:	2170	x: Monitor V	B:	2169
y: Flow (SCCM)	C:	1.6	y: Flow (SCCM)	C:	1.5
Correlation coeff:		0.999999	Correlation coeff:		0.999999

Figure 8-4 New Calibration Table

The columns of data entered into this screen are:

Control — This column of numbers represents the control voltage to the mass flow controller.

Monitor — This column represents the voltage output of the mass flow controller when it has stabilized after the control voltage has been applied. The monitor voltage should normally be very close to the control voltage.

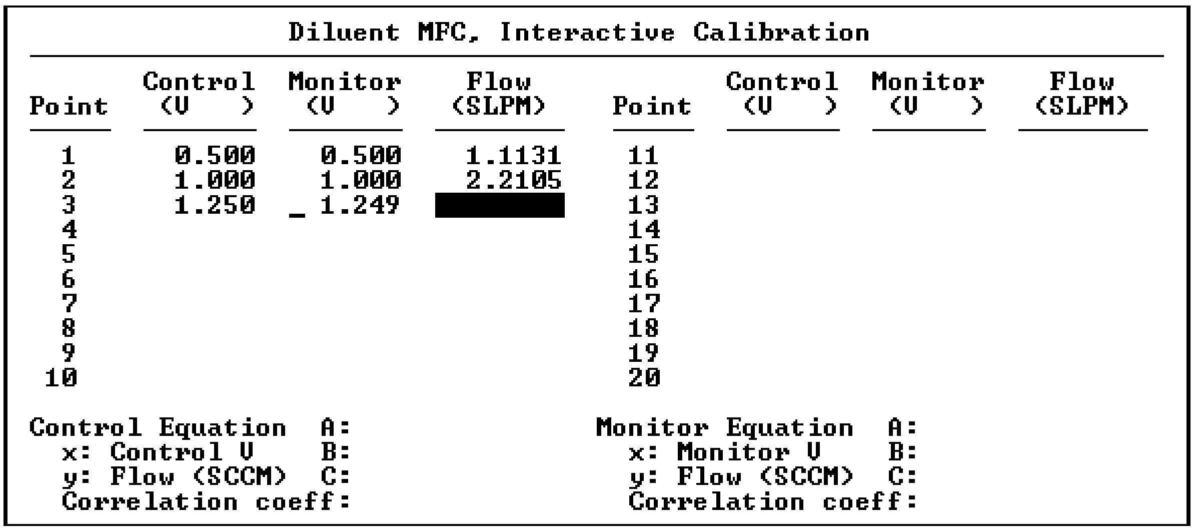
Flow — The flow column represents the actual flow, as measured by an external flow standard, through the flow controller when it has stabilized after the control voltage has been applied.

By pressing the F7 key while a number within a column is highlighted, that column’s units of measure can be changed; for example allowing voltages to be entered in units of Volts or mV and flows to be entered in SCCM or SLPM. Although the data may be entered in different units, any coefficients or linearization equations calculated from the table will be in terms of Volts (X) and SCCM (Y).

Once the data table has been entered, pressing the ESC key will cause a dialog box to appear, asking if you want to calculate the coefficients. Answering "yes" to this dialog causes the coefficients to be calculated and, if the linearization method is linear or polynomial, presented for review. One particular item to note at this point is the correlation. For mass flow controllers, the correlation should be very close to 1.0000, indicating a very close correlation to a straight line. The ozone generator, being slightly non-linear prior to calibration, will not normally correlate as closely to a straight line as an MFC. If everything looks good, answering "yes" again causes the changes to be saved.

Performing an Interactive Calibration

By selecting Interactive from the calibration menu, a lookup table can be generated by means of an interactive procedure. This procedure allows the user to enter a series of setpoint voltages, which are applied to the device, and then prompts for the value measured by the external reference to be entered.



Diluent MFC, Interactive Calibration

Point	Control (V)	Monitor (V)	Flow (SLPM)	Point	Control (V)	Monitor (V)	Flow (SLPM)
1	0.500	0.500	1.1131	11			
2	1.000	1.000	2.2105	12			
3	1.250	1.249		13			
4				14			
5				15			
6				16			
7				17			
8				18			
9				19			
10				20			

Control Equation A:
x: Control V B:
y: Flow (SCCM) C:
Correlation coeff:

Monitor Equation A:
x: Monitor V B:
y: Flow (SCCM) C:
Correlation coeff:

Figure 8-5 Interactive Calibration

Following is a description of the Interactive Calibration screen. The columns of data presented in the screen are:

Control This column of numbers represents the control voltage to the mass flow controller. This voltage is entered by the user for each setpoint and causes the voltage to be generated by the 4010 for the device being calibrated.

Monitor This column displays the measured voltage output from the device. The monitor voltage will normally be close to the control voltage. A large discrepancy may indicate a problem with the test setup.

Flow The flow column represents the actual flow or ozone concentration produced by the device for each control voltage.

Editing Calibration Data

Selecting Edit from the calibration menu allows either the polynomial coefficients or a lookup table to be edited. As with View, the type of data that can be edited depends upon how the data was entered; as a table or as coefficients.

Selecting Device Parameters

Ordinarily, it is not necessary to modify the device parameters, since the factory default values cover most applications, however if it is desirable the change the operating limits, allowable calibration error or the linearization method, these parameters can be altered by selecting Parameters from the devices calibration menu.

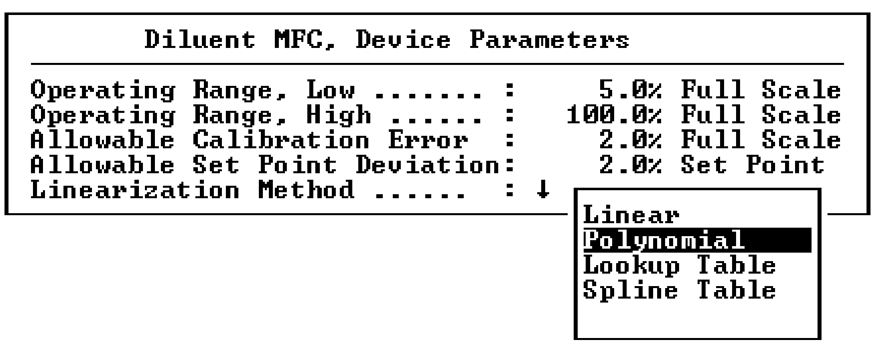


Figure 8-6 Device Parameters

Interactively Calibrating Mass Flow Controllers

The following step-by-step procedure describes how to perform a mass flow controller calibration using the interactive calibration feature.

[1] If power is not applied to the 4010, apply power to it and the mass flow standard and allow at least 30 minutes for everything to warm up and stabilize.

[2] The 4010's pneumatic system must be free of leaks before performing flow calibrations; particularly when calibrating the source flow controllers. If there is any doubt that the 4010 is leak-tight, perform a leak test.

[3] Attach a clean, dry compressed air or nitrogen supply to the diluent input for calibrating the diluent or ozone MFCs or to a source input if calibrating a source MFC. The pressure should be set to 20-25 PSIG.

[4] Cap all 4010 outlet ports except one. The un-capped port should be connected to the inlet of the flow standard. The outlet of the flow standard should be vented to atmospheric pressure.

[5] If the flow standard is a volumetric device, such as a bubble-meter, temperature and pressure corrections may be necessary in order to convert the measured flow rate to mass flow. If so, the barometric pressure in the room and the temperature of the gas should be measured. Ideally, the gas temperature sensor should be placed in the gas stream as it exits the flow standard, assuring that it measures the gas temperature in the flow standard. The barometric pressure is not likely to change during a calibration, however the gas temperature should be measured for each calibration point.

For environmental applications, mass flow controllers are typically calibrated to conditions of 25°C and 760 mmHg. The flow standard's operating manual should be consulted for instruction for converting its measured output to mass flow at 25°C and 760 mmHg.

[6] Select the method of linearization desired by selecting the Parameters item from the calibration menu and then selecting a method from the Linearization Method list (see Figure 8-6). For mass flow controllers, polynomial linearization is the recommended method.

[7] Select the Interactive option from the calibration menu. The screen shown in Figure 8-5 should appear.

[8] Enter the first control voltage in the left-most column. The 4010 will apply this voltage to the control input of the mass flow controller, causing a flow corresponding to that voltage to be produced.

[9] Observe that the monitor voltage approaches the control voltage, indicating that the MFC is sensing a flow. Once the monitor voltage has stabilized, wait another 60 seconds before taking a measurement.

[10] Take a measurement from the external flow standard. If the flow standard requires temperature and pressure correction, take a temperature reading and apply it and the room's barometric pressure to the measured flow in order to obtain a mass flow value. Enter this value into the column labeled "Flow" and press the Enter key. The cursor will advance to the next control voltage field.

[11] Repeat steps 8 through 10 until all calibration points have been entered.

[12] Press the ESC key. A dialog box will appear, asking if you want to calculate the coefficients. Answering "yes" will cause the calibration coefficients to be calculated and, if the linearization method is linear or polynomial, presented for review. One particular item to note at this point is the correlation. For mass flow controllers, the correlation should be very close to 1.0000 (e.g. 0.99999X), indicating a close correlation to a straight line. If everything looks good, answer "yes" again and the calibration will be saved.

Interactively Calibrating the Ozone Generator

The technique used for interactively calibrating the 4010’s ozone generator is almost identical to that used for a mass flow controller. The main differences are:

- An ozone generator calibration requires an ozone standard rather than a flow standard.
- The 4010’s outlet manifold must be vented to atmosphere for ozone generator calibrations.
- As shown in Figure 8-7, another field must be entered: the total flow through the 4010 during the ozone calibration. This is subsequently used to compensate the ozone output for different diluent flow rates.

Following is a step-by-step procedure for performing an interactive ozone calibration:

[1] If power is not applied to the 4010 and/or the ozone standard, apply power to both and allow at least 60 minutes for everything to warm up and stabilize.

[2] The 4010’s pneumatic system must be free of leaks before performing ozone calibrations. If there is any doubt that the 4010 is leak-tight, perform a leak test.

[3] Attach a clean, dry compressed air supply to the diluent input. Ideally, this would be the same supply subsequently used with the 4010 for analyzer calibrations. The pressure should be set to 25-30 PSIG.

[4] Cap all unused 4010 outlet ports, except one for a vent and one which should be connected to the inlet of the ozone standard. The last port in the flow path, the outlet labeled "Vent", should be vented to atmospheric pressure. If vented to the room, a short length of tubing should be attached to it. If vented through a scrubber or a long length of tubing, it is important to minimize the pressure drop so the outlet manifold remains substantially at atmospheric pressure.

[5] If the ozone standard does not incorporate automatic temperature and pressure correction, the barometric pressure in the room and the temperature of the gas should be measured. Ideally, the gas temperature sensor should be placed in the gas stream as it exits the ozone photometer, assuring that it actually represents the temperature of the gas in the photometer. The barometric pressure is not likely to change during a calibration, however the gas temperature should be measured for each calibration point.

[6] Select the method of linearization desired by selecting the Parameters item from the calibration menu and then selecting a method from the Linearization Method list (see Figure 8-6). For the ozone generator, the spline method is recommended.

[7] Select the Interactive option from the Ozone Generator Calibration menu. The following screen will appear:

Ozone Generator, Interactive Calibration

Point	Control (V)	Monitor (V)	Ozone (PPB)	Point	Control (V)	Monitor (V)	Ozone (PPB)
1	0.800	0.759	49.0	11			
2	1.000	0.963	138.0	12			
3	1.250	1.214	263.0	13			
4	1.750	1.719		14			
5				15			
6				16			
7				17			
8				18			
9				19			
10				20			

Total Flow Rate (Diluent + Ozone Flow) : 5.000 SLPM

Control Correlation: Monitor Correlation:

Figure 8-7 Interactive Ozone Calibration

[8] Enter the Total Flow Rate to a flow sufficient to supply the ozone standard (and any other analyzer that are drawing from the outlet manifold) plus a little excess flow from the outlet manifold’s vent. Ideally, this flow rate would be the same total flow that is typically used during ozone and GPT calibrations. After pressing F3 (or TAB), the 4010 will activate the diluent and ozone MFCs to produce the commanded total flow. Verify that there is excess flow from the manifold vent.

[9] In order to obtain the best accuracy, he calibration table should contain points below the lowest point needed during ozone or GPT calibrations and above the highest. Experimentally determine what control voltages are needed to produce these low and high ozone concentrations by entering a voltage in the left-most column and observing the resulting concentration as measured by the ozone standard. Pressing F2 (or Shift-TAB) will back up to allow another voltage to be entered.

Once the calibration voltage range has been bracketed, determine a set of control voltages needed to produce roughly equally spaced calibration points for the number of points desired. Before calibration, the ozone generator is slightly non-linear at the low end, so the voltage setpoints should be more closely spaced there.

[10] Enter the first control voltage in the left-most column. The 4010 will apply this voltage to the UV Power Supply which drives the ozone lamp, causing ozone to be produced.

[11] Observe that the monitor voltage approaches the control voltage, indicating that either the current or optical sensor is sensing that the lamp is active. Also observe the response of the ozone standard. It normally takes several minutes before the ozone standard reaches its final value.

[12] Once the ozone standard’s reading has stopped changing and reached a final value, take several measurements at intervals of 20 to 30 seconds and average them together. If the ozone standard requires temperature and pressure correction, take a temperature reading and apply it and the room’s barometric pressure to the measured ozone in order to obtain a corrected value. Enter this value into the column labeled "Ozone" and press the Enter key. The cursor will advance to the next control voltage field.

[13] Repeat steps 10 through 12 until all calibration points have been entered.

[14] Press the ESC key. A dialog box will appear, asking if you want to calculate the coefficients. Answering "yes" will cause the calibration coefficients to be calculated. If the spline linearization method is used, no coefficients will be displayed, but the linear correlation coefficient will be calculated. Since an uncalibrated ozone generator is more non-linear than a mass flow controller, the correlation will deviate from 1.0000 more than an MFC (e.g. 0.999XXX).

Section 9 Internal UV Ozone Photometer

This section describes the setup, operation and maintenance of the Model 4010's optional internal UV Ozone Photometer. When the Photometer option is installed in a Model 4010, it can be used to audit ozone calibrations, precisely control the 4010's internal ozone generator or it may be used independently, as a stand-alone ozone analyzer.

Description

The Model 4010 UV Photometer option consists of a module that is installed in the 4010's option bay. Two 50 pin ribbon cables carry power and electrical signals to and from the 4010's electronic module, resulting in a tightly integrated photometer subsystem.

The rear panel of the Photometer module (see Figure 4-1) supports the sample inlet, exhaust outlet and a connector (J9) that supports analog outputs for connection to external measuring devices such as a datalogger or strip chart recorder.

The Photometer's rear panel also supports two other connectors that are not directly related to the photometer. The Instrument Solenoid connector, J10, allows connection of externally controlled devices, such as solenoid valves, to the optional instrument solenoid control outputs. The Accessory connector, J11, allows an external permeation oven to be attached and controlled by the Model 4010.

Theory of Operation

The Model 4010 UV Ozone Photometer is a compact, single-tube, single-detector photometric device that measures ozone by monitoring 254nm ultraviolet light passing through a sample tube with an ultraviolet lamp at one end and a photo-detector at the other. Since this wavelength of light is attenuated by ozone, the ozone concentration can be determined by alternately observing the detector output when clean, ozone-free air is in the sample tube and when sample air is in the tube. An internal pump draws sample air into the photometer, where solenoid valves direct it either through or around a catalytic ozone scrubber before entering the sample tube.

The ratio of the detector output when ozone-free air is directed through the sample tube to the output when the sample air is in the tube determines the ozone concentration according to the following equation:

Equation 9-1

$$Ozone\ (PPB) = \frac{(T+273)}{273} \times \frac{760}{P} \times \frac{10^9}{(a \times L)} \times \ln\left(\frac{I_o}{I}\right)$$

Where:

- α = Absorption Coefficient of ozone at 254nm and with the sample gas at 0°C and 760 mmHg = 308
- L = Optical Path Length = 31.6 cm
- I = Sample Count (Conditioned detector output for sample gas)
- I_o = Reference Count (Conditioned detector output for clean air)
- T = Sample Temperature (°C)
- P = Sample Pressure (mmHg)

In order to increase the resolution of measurements and improve accuracy, the detector's signal conditioning circuitry amplifies and offsets the detector signal such that, the voltage observed on the 4010's analog input represents only a small window in the overall range of light impinging on the detector.

Since the attenuation due to the presence of ozone is very small, this is not a problem, but before the analog value measured from the detector conditioning circuitry can be used in the ozone equation, it and must be converted back to a light intensity value. Since the ozone calculation is based on a ratio, the scaling of this value is not important; only that the value represents actual light intensity and that darkness is zero.

The following equation is used to convert the detector voltage to a unit-less number or "count" that may subsequently be used as I or I_o in the previous equation:

Count (I or I_o) = (Voltage + Offset x Gain) x 10000

The values of the Offset and Gain are presented in the Photometer Parameters screen. The number 10000 is an arbitrary value that is used to convert the result to an large integer.

Installation

When a Model 4010 is ordered with the Photometer option, the Photometer module is delivered pre-installed in the 4010's option bay. All pneumatic connections to the Photometer are external, allowing the user to make the choice of where to monitor the ozone. In most cases, the photometer's sample inlet will be connected to an unused port of the 4010's outlet manifold, allowing it to directly monitor the 4010's ozone production during ozone calibrations. When the 4010 is shipped, nothing is connected to the Photometer's inlet, however a short length of Teflon tubing is provided for connection to the outlet manifold.

Operation

There are three basic modes of operation for the Model 4010's UV Ozone Photometer. These are:

Audit Mode	In Audit Mode, the Photometer is used to measure the ozone output of the Model 4010 and serves as an independent audit device.
Ozone Servo Mode	In this mode, the Photometer's measurement is used to automatically adjust the 4010's internal ozone generator. This results in a precise ozone concentration that is independent of temperature, pressure, humidity and other factors that can affect ozone production.
Continuous Mode	Ordinarily, the Photometer is activated only during ozone calibrations. In Continuous Mode, however, the Photometer will remain active continuously while power is applied to the 4010. This feature allows the 4010's Photometer to be operated independent of the 4010's other functions as a stand-alone ozone monitor.

After determining what mode of operation is to be used, the mode should be selected by clicking the appropriate checkboxes in the Photometer Parameters screen, as described on Page 10. Other than customizing the analog outputs for a specific application, the operating mode is the only setup function that is normally necessary to operate the 4010's Photometer.

Unless Continuous Mode is selected (in which case the Photometer is always active), the 4010 will automatically activate the Photometer any time that an ozone point or sequence begins. The Photometer will not be activated, however, during GPT calibrations.

The ozone value, as measured by the Photometer, will be transmitted from the three analog outputs and will also be presented as the "Measured Ozone" value in the Photometer section of the Ozone Calibration Status screen (see Figure 9-1). This section of the status screen (which may also be called up by selecting "Photometer Status from the "Status" menu) not only presents the current ozone concentration, but also provides the current readings of the various sensors and solenoid valves associated with the Photometer.

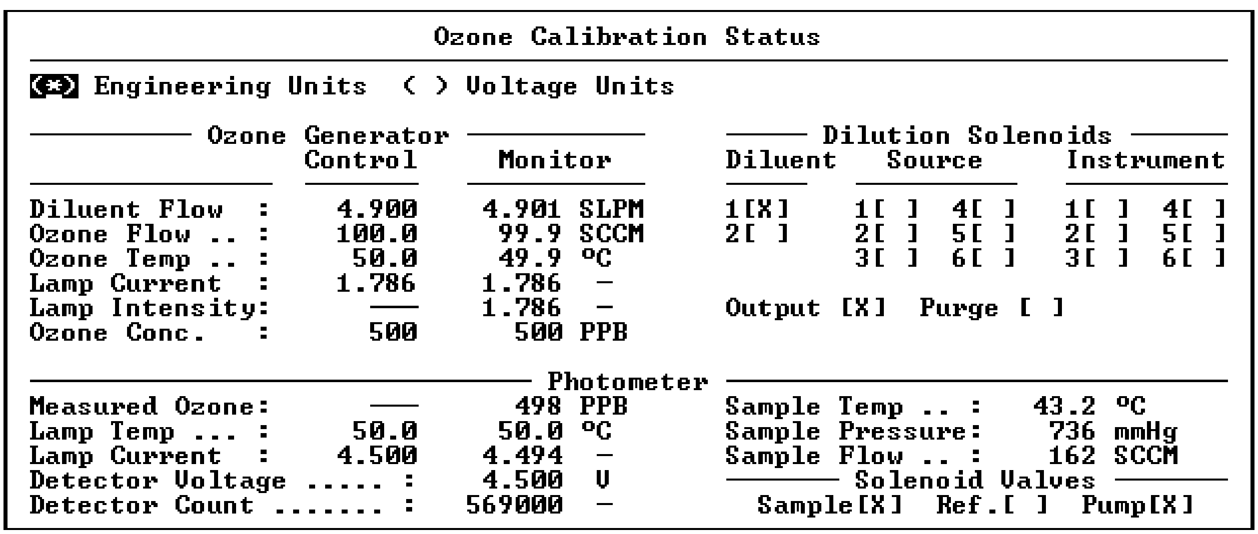


Figure 9-1 The Ozone Status Screen

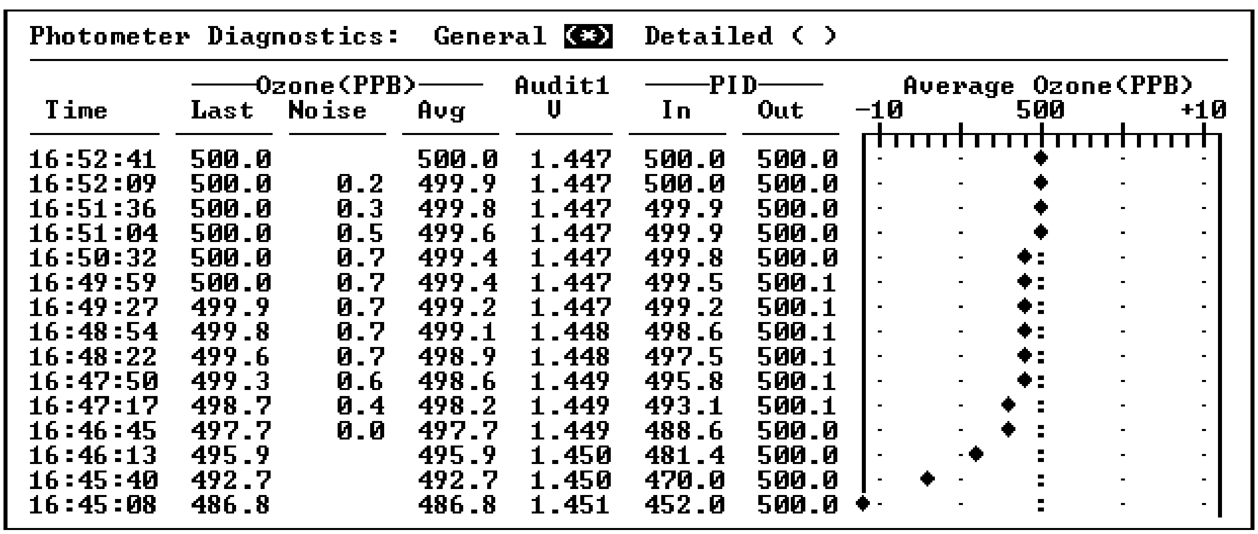
Following are descriptions of the items that may be found in the Photometer section of the Ozone Calibration Status screen:

Measured Ozone	The Measured Ozone presents the average ozone measured by the Photometer.
Lamp Temp	The Control and Monitor values of the Photometer lamp temperature is presented here.
Lamp Current	This is a unit-less number, between 0 and 5, that is proportional to the current applied to and measured from the Photometer's UV lamp.
Detector Voltage	This is the voltage that is presented to the 4010's A/D converter after signal conditioning the detector's output. The voltage displayed here should never approach zero or five Volts. If it does, the automatic lamp adjustment procedure described on Page 19 should be invoked.
Detector Count	The detector count is the value that is actually used in the Photometer equation on Page 2. It is a unit-less value that is derived by applying the Detector Offset and Gain Parameters to the Detector Voltage.
Sample Temperature	This is the temperature of the sample gas in the measurement tube as measured by the Photometer's temperature sensor. This is used to compensate the ozone value for temperature variations.
Sample Pressure	This is the pressure in the measurement tube as measured by the Photometer's pressure sensor. This is used to compensate the ozone value for pressure variations.

Sample Flow This is the flow through the Photometer as measured by the Photometer's flow sensor.

Solenoid Valves The states of the reference and sample solenoid valves and the pump are indicated here. An "X" indicates that the valve or pump is active.

Another valuable source of information about the current status of the 4010's Photometer is the Photometer Diagnostics screen, which may be selected from the "Diag" menu. Figure 9-2 shows the "General" Photometer Diagnostics screen, which presents status information about the last fifteen Photometer cycles in a tabular format, with the most recent value on top. Each time the Photometer completes a cycle, the data will scroll down to make room for the new data.


Photometer Diagnostics: General (*) Detailed ( )

Time	Ozone(PPB) Last	Noise	Avg	Audit1 V	PID In	Out
16:52:41	500.0		500.0	1.447	500.0	500.0
16:52:09	500.0	0.2	499.9	1.447	500.0	500.0
16:51:36	500.0	0.3	499.8	1.447	499.9	500.0
16:51:04	500.0	0.5	499.6	1.447	499.9	500.0
16:50:32	500.0	0.7	499.4	1.447	499.8	500.0
16:49:59	500.0	0.7	499.4	1.447	499.5	500.1
16:49:27	499.9	0.7	499.2	1.447	499.2	500.1
16:48:54	499.8	0.7	499.1	1.448	498.6	500.1
16:48:22	499.6	0.7	498.9	1.448	497.5	500.1
16:47:50	499.3	0.6	498.6	1.449	495.8	500.1
16:47:17	498.7	0.4	498.2	1.449	493.1	500.1
16:46:45	497.7	0.0	497.7	1.449	488.6	500.0
16:46:13	495.9		495.9	1.450	481.4	500.0
16:45:40	492.7		492.7	1.450	470.0	500.0
16:45:08	486.8		486.8	1.451	452.0	500.0

Figure 9-2 The Photometer Diagnostics Screen, General

On the right side of the General Photometer Diagnostics screen is a simulated strip chart that presents the latest average ozone measurements taken from the Photometer. The strip chart always presents a 20 PPB range centered around the currently desired ozone setpoint, allowing the deviation from the desired ozone concentration to be observed in a graphical format. This chart is particularly useful for observing the ozone response when the ozone servo control is active.

The other columns of information are described below:

Last Ozone
The Last Ozone is the unaveraged or "raw" Photometer measurement for each Photometer cycle.

Noise
The noise column presents the standard deviation of the raw ozone values during the rolling average period. This is a good indicator of how noisy the photometer measurements are.

Average Ozone
The Average Ozone presents the average of the last *N* raw ozone readings, where *N* is the Rolling Average duration as set in the Photometer Parameters screen. This is the value displayed on the Ozone Calibration Status screen as "Measured Ozone".

Audit 1
The Audit 1 column of numbers presents the voltage (between 0.000 and 5.000 Volts) that is measured on the first Audit analog input. An external ozone standard or other analog device may be connected to the Audit 1 input, which is found on Audit connector pins J7-6(+) and J7-19(-). A complete wiring list of the Audit connector can be found in the Installation section of the 4010 manual.

PID In
This is the filtered input to the PID control loop processor. It is derived by filtering the raw ozone values obtained from the Photometer.

PID Out
The PID Out column of values represents the output of the PID loop processor. This value is used to set the ozone generator's lamp current in order to adjust for deviations measured by the photometer.

The "Detailed" Photometer diagnostics presents more detailed information about the photometer. Rather than updating each photometer cycle, it presents new information each half-cycle, allowing the reference and sample data to be observed. Figure 9-3 shows an example of the Detailed Photometer Diagnostics screen.

Photometer Diagnostics: General ( ) Detailed (*)

			Ozone (PPB)			Sample		Lamp	O3Gen	Audit1
Time	Ref.	Sample	Last	Noise	Avg	mmHg	°C	°C	PPB	V
16:52:41	570000		500.0		500.0	706.2	42.11	49.82	500.0	1.447
16:52:25		567233	500.0	0.1	500.0	706.2	42.11	49.82	500.0	1.447
16:52:09	570000		500.0	0.2	499.9	706.2	42.11	49.82	500.0	1.447
16:51:52		567233	500.0	0.2	499.9	706.2	42.11	49.82	500.0	1.447
16:51:36	570000		500.0	0.3	499.8	706.1	42.14	49.79	500.0	1.447
16:51:20		567233	500.0	0.4	499.7	706.1	42.14	49.79	500.0	1.447
16:51:04	570000		500.0	0.5	499.6	706.1	42.14	49.79	500.0	1.447
16:50:48		567233	500.0	0.7	499.5	706.1	42.14	49.79	500.0	1.447
16:50:32	570000		500.0	0.7	499.4	706.1	42.18	49.90	500.1	1.447
16:50:15		567233	500.0	0.7	499.4	706.1	42.18	49.90	500.1	1.447
16:49:59	570000		500.0	0.7	499.4	706.1	42.18	49.90	500.1	1.447
16:49:43		567233	500.0	0.7	499.3	706.1	42.18	49.90	500.1	1.447
16:49:27	570000		499.9	0.7	499.2	706.1	42.23	49.93	500.1	1.447
16:49:11		567233	499.9	0.7	499.2	706.1	42.23	49.93	500.1	1.447
16:48:54	570000		499.8	0.7	499.1	706.2	42.27	49.97	500.1	1.448

Figure 9-3 The Photometer Diagnostics Screen, Detailed

Many items found in the detailed screen are the same as the general screen, however there are a few additional items. They are:

Ref. This is the detector reading during the reference half of the Photometer cycle, after being converted to a unit-less number or "count".

Sample This is the detector count during the sample half of the Photometer cycle. The ratio of the reference count to the sample count is used to calculate the ozone concentration as described on Page 2.

Sample Pressure (mmHg) This is the pressure in the measurement tube as measured by the Photometer's pressure sensor.

Sample Temperature (°C) This is the temperature of the sample gas in the measurement tube as measured by the Photometer's temperature sensor.

Lamp Temperature (°C) This is the temperature of the heated Photometer lamp block.

Setup Options

The Model 4010's photometer is adjusted, calibrated and all parameters pre-set for optimal operation in the standard configuration prior to delivery to the customer. As such it is normally not necessary or desirable to modify the operating parameters of the Photometer. There are circumstances, however, when performance could be improved by adjusting one or more of these parameters.

--- CAUTION ---

> Making changes to parameters in the Photometer Parameters screens can cause the photometer and/or ozone generator to operate incorrectly or erratically and should only be attempted with a thorough understanding of the Photometer and the relationship of each parameter. In any case be sure to record the original factory settings before attempting changes.

The photometer Parameters may be viewed or changed by selecting "Devices" from the main menu, then "Ozone Photometer" and then "Photometer Parameters". The Photometer Parameters are presented on three pages. The first page is shown in Figure 9-4.

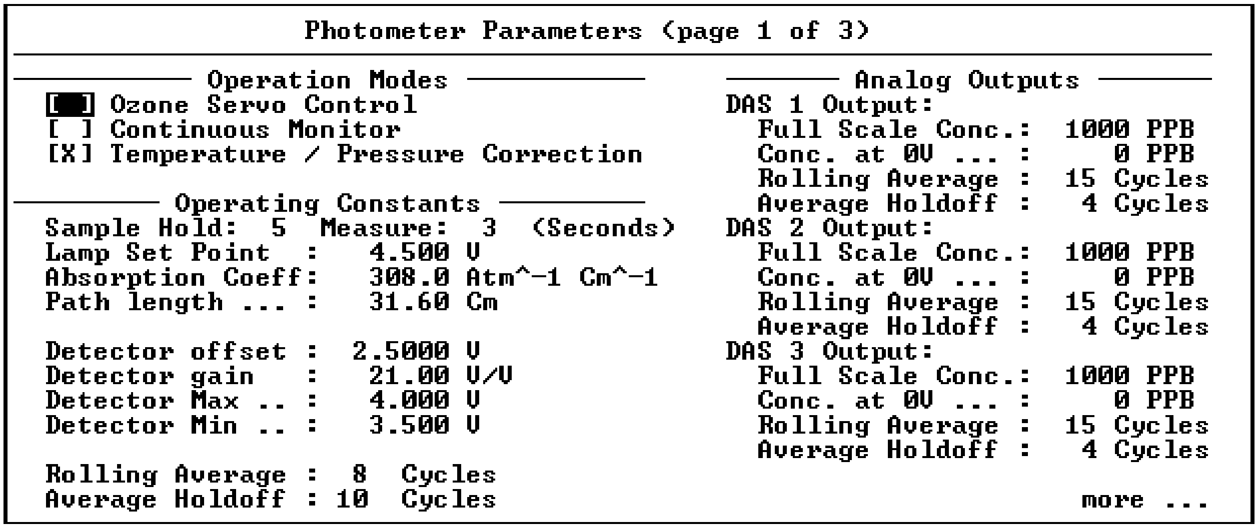


Figure 9-4 Photometer Parameters, Page 1 of 3

In the upper left corner of the Photometer Parameters screen, the operating mode of the Photometer can be changed by clicking the following checkboxes:

Ozone Servo Control When this box is checked, the ozone measured by the Photometer will be used to automatically adjust the 4010's ozone generator while an ozone calibration is being performed.

Continuous Monitor By checking this box, the Photometer will remain active continuously while power is applied to the 4010.

Temp. / Pressure Correction The Photometer is normally operated with temperature/pressure correction enabled, however under certain circumstances, such as when comparing the 4010's Photometer with an external ozone monitor that does not support temperature/pressure correction, it may be desirable to temporarily disable this feature by unchecking this box.

Below the Operating Modes section are the Operating Constants, which govern the operation of the photometer and should not normally be changed. Following are descriptions of these parameters:

Sample Hold — The Sample Hold time is the number of seconds to allow after the sample/reference solenoid valves are switched before detector readings are taken. This time period is necessary in order to allow the sample or reference gas to fully fill the sample tube.

Sample Measure — The Sample Measure time is the number of seconds of data to collect from the detector after the Hold Time has elapsed before switching the sample/reference solenoid valves. The data collected during this time is averaged in order to reduce noise.

Lamp Setpoint — This is the voltage applied to the Photometer's UV lamp drive. This should be set to a value between 0 and 5 Volts such that the detector output is between the Detector Min and Detector Max during the reference half of the Photometer cycle. Normally this is done automatically by invoking the lamp adjustment procedure described later.

Detector Offset and Gain — The Detector Gain and Offset parameters are factory set to reflect resistor values on the Lamp Drive Board that cause the detector signal to be amplified and offset. These parameters are needed in order to calculate the ozone concentration and should not be changed from their factory settings.

Detector Max and Min — The Detector Max and Min parameters determine the range of the detector signal that is considered acceptable by the automatic lamp adjustment procedure.

Rolling Average	A rolling average is optionally applied to the calculated ozone concentration in order to reduce the variability that is intrinsic in this type of measurement. The Rolling Average parameter determines how many photometer cycles are included in this average.
Average Holdoff	In order to improve the response time of the Photometer during ozone calibrations, this parameter may be set to control how many photometer cycles to wait after the ozone generator setpoint has changed before the rolling average is activated.

The following parameters are used to set up the analog outputs (DACs) for a particular application. By changing these parameters, the outputs may be scaled and filtered as needed:

DAC Full Scale Conc.	This is the ozone concentration that corresponds to 5 Volts on the analog output. The units of measure for this concentration may be changed by pressing the F7 key when the parameter is selected.
DAC Conc. At 0V	This is the ozone concentration that corresponds to zero Volts on the analog output. By setting this to a value other than zero, an offset can be introduced. The units of measure for this concentration may be changed by pressing the F7 key when the parameter is selected.
DAC Rolling Average	Each DAC may be set up with a different Rolling Average duration. See the Rolling Average parameter described above, in the Operating Constants section.
DAC Average Holdoff	Each DAC may be set up with a different Average Holdoff. See the Average Holdoff parameter described above, in the Operating Constants section.

The second page of the Photometer Parameters, shown in Figure 9- contains scaling factors for the various sensors associated with the photometer. For each sensor, there is a sensor equation (and a control equation for the Lamp Temperature) that allows the sensor to be calibrated precisely by setting the three polynomial coefficients. Note that if the C coefficient is set to zero, the A and B coefficients will correspond to the intercept and slope, respectively, of a simple linear equation. With the exception of the sample flow, the Photometer's sensors are very linear.

Of these sensors, the Sample Temperature and Pressure are the most critical, since they are used to compensate the ozone measured by the Photometer for temperature and pressure variations. The Lamp Temperature and Sample Flow are provided as diagnostic tools.

```
                    Photometer Parameters (page 2 of 3)         more ...
-------------------------------------------------------------------------
------ Lamp Temperature ----------      ------ Sample Temperature -------
  Set Point ....... :  50.0 ºC            Sensor Equation  A:      0.00
  Low  Temp Alarm   :  48.0 ºC              y=A+Bx+Cx^2    B:    25.000
  High Temp Alarm   :  52.0 ºC              x: Volts       C:    0.0000
                                            y: Temp (ºC)
  Sensor Equation  A:      0.00
    y=A+Bx+Cx^2    B:    25.000         ------ Sample Pressure ----------
    x: Volts       C:    0.0000           Sensor Equation  A:     -86.2
    y: Temp (ºC)                            y=A+Bx+Cx^2    B:    344.67
  Control Equation A:      0.00             x: Volts       C:     0.000
    y=A+Bx+Cx^2    B:    25.000             y: Press (mmHg)
    x: Volts       C:    0.0000
    y: Temp (ºC)
  --------------------------- Sample Flow --------------------------------
    Low  Flow Alarm :   250 SCCM          Sensor Equation  A:       0.0
    High Flow Alarm :   750 SCCM            y=A+Bx+Cx^2    B:    -60.00
                                            x: Volts       C:    50.000
                                            y: Flow (SCCM)          more ...
```

Figure 9-5 Photometer Parameters, Page 2 of 3

Following are brief descriptions of the various sensors:

Lamp Temperature — The setpoint, high and low alarms and the sensor and control equations may be altered in this section. Ordinarily it is not necessary to change these parameters.

Sample Flow	The sample flow sensor provides an indication of the flow through the photometer. Note the high value of the C coefficient, which indicates that, before it is processed by the 2nd order polynomial, the flow sensor's signal is very non-linear.
Sample Temperature	The sample temperature sensor is used to temperature compensate the measured ozone. An incorrect calibration of this sensor will result in erroneous ozone measurements.
Sample Pressure	The sample pressure sensor is used to pressure compensate the measured ozone. When the Photometer is inactive and the pump is off, the Sample Pressure, as viewed in the status screen, should indicate the room's barometric pressure. An incorrect calibration of this sensor will result in erroneous ozone measurements.

The third page of the Photometer Parameters, shown in Figure 9-, contains parameters that govern the servo control of the ozone generator when the Ozone Servo Control option is selected on page 1. If anything other than the standard configuration of the photometer and ozone generator is used, it may be necessary to adjust these constants in order to "tune" the servo loop. A more detailed description about setting the constants on this page is given in the section "***so that it will not affect other scheduled instrument automatic calibrations.***

Ozone Servo Control Adjustments", beginning on page 9-20.

```
                 Photometer Parameters (page 3 of 3)          more ...

──── Ozone PID Servo Loop Constants ──────

  Proportional Term Constant :  0.400
  Integral Term Constant ... :  0.180
  Derivative Term Constant   :  0.130

  PID Filter ............... : 12 Cycles
  Filter Holdoff ........... :  2 Cycles
  PID Holdoff .............. : 10 Cycles
```

Figure 9-6 Photometer Parameters, Page 3 of 3

--- CAUTION ---

Making changes to these parameters could cause the ozone generator to operate improperly or even to oscillate wildly when the ozone servo mode is selected. Be sure to record the original factory settings before attempting changes.

Following are brief descriptions of the PID Servo Loop Constants:

Proportional Term Constant The Proportional constant is multiplied by the proportional term of the PID equation. This term is the difference, or error, between the current measured value and the desired setpoint. The Proportional constant will normally be less than 1 for Photometer servo control.

Integral Term Constant

The Integral constant is multiplied by the integral term of the PID equation. This term represents the integral or accumulated sum of all the errors since the PID loop was activated. This constant will also normally be less than 1 for photometer servo control.

Derivative Term Constant

The Derivative constant is multiplied by the integral term of the PID equation. The derivative term represents the current rate-of-change of the error. The derivative term is normally small or zero.

PID Filter

The PID Filter smoothes the Photometer's measurements prior to the PID equation. This is necessary since excessive Photometer noise can cause the PID loop to attempt to compensate for variations that are merely cause by noise. The value entered for the PID Filter is the number of photometer cycles to use as the filter's time constant.

Filter Holdoff

This is the number of photometer cycles to wait after a change in the ozone setpoint before beginning the PID filter.

PID Holdoff

This is the number of photometer cycles to wait after a change in the ozone setpoint before activating the PID servo control. This is normally set such that the Photometer's natural response to an ozone change has stabilized before the PID loop is activated for final adjustments.

Photometer Calibration

The Photometer can be calibrated against an external ozone standard by selecting "Ozone Photometer" and then "Ozone Calibration" from the "Devices" menu. As can be seen in the Figures, below, the photometer calibration operates in a fashion almost identical to the calibration of the ozone generator.

Photometer, Edit Calibration Table

Point	Photometer (PPB)	Reference (PPB)	Point	Photometer (PPB)	Reference (PPB)
1	41.2	41.0	11		
2	77.6	77.0	12		
3	163.4	163.0	13		
4	330.9	321.0	14		
5	500.3	482.0	15		
6	671.0	643.0	16		
7	839.9	809.0	17		
8	1008.8	969.0	18		
9	1173.9	1120.0	19		
10			20		

Sample Temperature :	36.2 °C	Monitor Equation A:	2.4
Sample Pressure .. :	689 mmHg	x: Photometer B:	0.9670
Sample Flow ...... :	820 SCCM	y: Reference C:	-1.126E-05
Lamp Temperature :	52.1 °C	Correlation coeff:	0.999978

Figure 9-7 Photometer, Edit Calibration Table

Photometer, Interactive Calibration

Point	O3Gen (V)	Photometer (PPB)	Reference (PPB)	Point	O3Gen (V)	Photometer (PPB)	Reference (PPB)
1	1.000	194.2	195.0	11			
2	1.500	399.3	405.0	12			
3	2.000	508.9		13			
4				14			
5				15			
6				16			
7				17			
8				18			
9				19			
10				20			

Total Flow Rate (Diluent + Ozone Flow) : 5.000 SLPM

Sample Temperature :	43.1 °C	Monitor Equation A:	
Sample Pressure .. :	728 mmHg	x: Photometer B:	
Sample Flow ...... :	158 SCCM	y: Reference C:	
Lamp Temperature :	50.0 °C	Correlation coeff:	

Figure 9-8 Photometer, Interactive Calibration

For more details on performing internal calibrations with the 4010, refer to Section 8, "Internal Calibrations". Though the Photometer calibration is very similar to other internal calibrations, there are a few differences and considerations that should be addressed:

- The other internal calibrations have both control and monitor correction equations. The Photometer, being a measurement-only device has only a monitor equation.
- Other internal calibrations are used not only for adjusting for calibration errors, but also for converting voltage units to engineering units of measure. For example, for ozone generator calibrations, the control and monitor values are both in voltage units, while the external ozone standard is in terms of concentration (PPB, PPM, etc.). In the case of the Photometer, however, both the Photometer (monitor) and external ozone standard values are in terms of concentration units.
- The values entered into the O3Gen column during an interactive Photometer calibration are used to activate the ozone generator in order to produce an ozone concentration for comparison of the Photometer and external ozone standard. This column of values is not used to calculate Photometer calibration coefficients.
- The Sample Temperature, Pressure, Flow and Lamp Temperature are provided so a record of the environmental conditions at the time of the calibration will be known. Though these parameters are provided automatically when an interactive calibration is performed, they are optional and may be omitted if manually entering calibration data.
- IMPORTANT: The "Photometer" column of numbers in the New or Edit Table screens (Figure 9-) represents the <u>uncalibrated</u> photometer reading. If a calibration table is to be generated manually by comparing the photometer to an external standard, the previous calibration should be removed first by selecting "New Coefficients" under the "Photometer Calibration" menu and setting the Photometer coefficients A, B and C to 0, 1 and 0, respectively. If this is not done, the resulting calibration table will be erroneous, since a calibration will have been applied on top of a previous calibration. This is not necessary when an interactive calibration is performed, since the automatically supplied Photometer reading is always the uncalibrated value.

Lamp Adjustment

The Photometer detector's surface is directly illuminated by the UV lamp after passing through the sample tube, producing a large signal. The attenuation of this detector signal due to the presence of ozone in the sample gas is very small compared to the signal caused by the lamp's direct light.

In order to improve the resolution and sensitivity of the detector signal, the signal is amplified by a gain factor and then offset such that the 4010 actually views only a small window of the detector's signal range. As the lamp ages, it is possible for the detector signal to drift outside this measurement window, resulting in erroneous ozone measurements.

When this occurs, it is necessary to adjust the lamp either by changing the Lamp Setpoint or by invoking the automatic lamp adjustment procedure. Once started, the automatic lamp adjustment procedure will try various Lamp Setpoint values until the detector signal falls between the Detector Max and Min parameters, which are set in the Photometer Parameters screen.

Before using the automatic lamp adjustment procedure, the 4010 should be idle and the 4010 should have been powered up at least one hour in order that the photometer lamp block has reached temperature and the lamp is stable. The lamp adjustment procedure can be initiated by selecting "Devices" from the main menu, then "Ozone Photometer" and then "Photometer Lamp Adjust". No alternate window will appear after the “Photometer Lamp Adjust” is initiated, however the adjustment values can be viewed on the bottom portion of the main screen.

The lamp adjustment begins by setting the Photometer lamp to 2.5 Volts. The voltage on the detector is then observed to determine whether the lamp intensity is too low or too high in order that the next "guess" at the correct lamp Voltage may be made. This process continues until a lamp Voltage is reached that causes the detector output to fall within the Detector Max and Min values.

While the lamp adjustment procedure is active, the lamp Voltage, Detector Voltage and last detector Voltage values will be presented on the status line, labeled as V, D, and LD, respectively. If the procedure is successful a message displaying “Lamp Adjust Successful” will appear on the bottom portion of the main window. Otherwise, the message “Lamp adjust Failed” will appear. If the lamp adjustment fails you should initiate the procedure again. Additional maintenance may be required if the lamp adjust continues to fail. You may need to manually adjust the lamp or replace it depending on advice from the factory.

Automatic Lamp Adjustment

To insure that the detector signal is maintained throughout the monitoring period, it may be more practical to schedule the lamp adjustment from the existing Photo Adjust Sequence or create a new sequence for the procedure. Units that are shipped from the factory with photometers already have the sequence titled “Photo Adjust” in the sequence menu. Alternatively, units with the software 1.08.06 and older can have the sequence created.

Creating the sequence can be accomplished by following the procedures titled “Introduction to Initializing Calibration Sequences” starting on page 6-7 or by creating an ozone sequence with the name of “Photo Adjust” and setting a zero point for a duration of 15 minutes.

Whether you are creating the sequences or simply using the predefined sequence in the sequence menu, you will still need to schedule the sequence in order for the lamp adjust to occur. Details about how to schedule a sequence can be found in the sub-section titled “Scheduling Automatic Calibrations” on page 6-21.

CAUTION

Do not set the frequency of the adjust for too short of a period or you will cause the lamp to age much more rapidly than necessary. The lamp intensity reading on the photometer status screen can drop to 2.00 volts without affecting the photometer performance. It is recommended that a frequency of three to seven days be applied for best results. Also, make sure to have the lamp adjust occur so that it will not affect other scheduled instrument automatic calibrations.

Ozone Servo Control Adjustments

When Ozone Servo Control is selected in the Photometer Parameters screen, the Model 4010 utilizes PID control in order to control the ozone generator based on the Photometer's measurements. The ozone servo control loop is adjusted or "tuned" at the factory for optimum performance when the Photometer's inlet is connected to the 4010's output manifold and when both the photometer and ozone generator are calibrated. If the photometer is connected elsewhere, for example to an external sample manifold, it will be necessary to re-tune the loop by adjusting these constants.

Many books have been written about control theory and PID control and about setting the three main constants of the PID equation: the Proportional, Integral and Derivative constants. The process of setting these constants is called "tuning" and is considered by many to be an art rather than a science.

Although a thorough discussion of control theory and the tuning of PID loops is outside the scope of this manual, a few pointers and tips may give a user unfamiliar with PID control a chance of successfully tuning the 4010's servo loop using a trial-and-error approach. In general, adjusting the PID constants is a lengthy and painstaking process that should be avoided if possible, however for those brave hearts that want to attempt it, here are a few general tips, pointers and suggestions:

- If at all possible, use the standard configuration with the Photometer's inlet attached via a short length of Teflon tubing to the 4010's inlet manifold. In this configuration, it should not be necessary to alter the factory tuning constants.
- Be sure the ozone generator is calibrated such that its output matches the 4010's photometer. The factory tuning assumes that when the ozone generator is commanded to produce an ozone concentration when servo control is disabled, the photometer will measure that concentration within a few percent.

  Before attempting any changes, write down (or print using the report button) the factory settings in all three pages of the Photometer Parameters screen.
- For the standard configuration, initially tune the servo loop using the 4010's "Fake Hardware" mode. In this mode, all analog and digital I/O is replaced by simulated hardware. In particular, care has been taken to make the photometer simulation as close to the real thing as possible, at least for the standard configuration with the Photometer inlet attached to the 4010's outlet manifold. The Fake Hardware mode may be selected by typing ALT-H on an external keyboard.
- When in Fake Hardware mode, it is possible to temporarily reduce the photometer cycle time by setting the Sample Hold to 0 and Sample Measure to 1. These parameters can be changed on page 1 of the Photometer Parameters screen. This will speed up the testing process without affecting the actual PID tuning.

- In order to force a servo loop adjustment to be necessary, temporarily change the Photometer's calibration by entering new coefficients in the Photometer Calibration under the Devices menu (after first recording the current Photometer calibration). For example, setting the A, B and C coefficients to 0, .95 and 0 will cause about a -5% span error that the PID loop must adjust for. After arriving at a set of PID constants, try varying the B coefficient and observing how the loop responds.
- Use the strip chart in the Photometer Diagnostics screen to observe the response of the photometer as its measurement closes in on the setpoint value. Alternatively, an external strip chart recorder attached to a photometer DAC output could be used to provide a more detailed picture of the response characteristic.
- Set the PID Holdoff such that the PID loop does not become active until the Photometer's measurement has approximately reached a final value on its own. This greatly improves initial response time. For the standard configuration, it takes about 10 cycles (at 16 seconds per cycle) for the photometer's reading to stabilize after an ozone setpoint change.

  Initially, set the PID filter to about 12 and the Filter Holdoff to about 2. This provides pre-filtering of the Photometer's measured ozone data. It is important to remove as much noise as possible to avoid excessive wandering of the servo loop as it tries to correct for random noise. Increasing the PID Filter too much could adversely affect response time of the loop.
- Start out with the Derivative term set to zero. It is possible (and simpler) to tune the servo loop using only the Proportional and Integral terms. If there is a slight overshoot, however, the Derivative term can sometimes be increased slightly to eliminate the overshoot, rather than decreasing the Integral term, resulting in an improved response time.
- Start out by selecting the factory default Proportional and Integral terms (about .4 and .2, respectively). With the Proportional constant remaining fixed, increase the Integral constant if the photometer takes too long to reach the setpoint value and decrease it if there is overshoot or oscillation. The best Proportional constant value can be found by trying different values, but for each new Proportional constant, the Integral constant bust be readjusted to compensate for undershoot or overshoot.

- After setting the constants using the Fake Hardware mode, resume normal mode (by entering ALT-H) and run tests with the real Photometer and Ozone Generator. Be sure to restore the original Sample Hold and Measure times. The response may be somewhat different than that while using the simulated Photometer, requiring additional adjustment of the PID constants. Test that the servo control operates properly even when the photometer calibration is high or low.

Routine Maintenance

The Model 4010's Photometer is designed to operate with minimal maintenance, however periodic maintenance will ensure that the Photometer continues to operate in the optimum condition. In addition, there are several components in the Photometer that should be considered expendable and that will need periodic replacement. This section describes the common maintenance items, beginning with those requiring the most frequent attention.

Calibration

In order to ensure the accuracy of the 4010's Photometer, it should be calibrated periodically by comparing it to an ozone reference standard. This will not only ensure that the Photometer's measurements are accurate, but will also point out when there is a problem and maintenance is needed. The sub-section entitled "Photometer Calibration" beginning on Page 9-17 describes how to calibrate the 4010's Photometer.

Lamp Adjustment

The Photometer's UV lamp directly illuminates the detector's surface after passing through the sample tube. This produces a large signal on the output of the detector. The attenuation of this detector signal due to the presence of ozone in the sample gas is very small compared to the signal caused by the lamp's direct light.

The sub-section entitled “Lamp Adjustment” beginning on Page 9-19 describes how to properly adjust the lamp for optimum detector efficiency.

Inlet Filter Replacement

A Teflon filter on the inlet of the Photometer may be provided to protect the Photometer form particulate matter that could otherwise contaminate the pneumatic pathways. Newer versions of the Model 4010 supply zero air from the alternate air port provided from the dilution stream. In this instance, the air should be particulate free, thus the need for a filter is not required. Otherwise, dust can have an adverse effect on the Photometer's accuracy, since accumulated contaminants may react with ozone, causing an apparent span error.

Although the Model 4010 Photometer is ordinarily exposed to less dust than ambient ozone analyzers, since it is usually sampling ozone in a clean air stream rather than that in ambient air, the filter should be replaced periodically to prevent the effects of accumulated dust. The filter is contained in a Teflon housing which is attached to the Photometer's rear panel, directly behind the sample inlet. The filter can be changed from the rear panel, without opening the 4010.

The inlet filter may be changed by following the steps listed below:

[1] Make sure the Photometer's pump is off, otherwise unfiltered air from the room could be drawn into the Photometer, contaminating the pneumatics.

[2] Remove the sample inlet tube.

[3] Remove the four screws securing the filter housing retaining plate.

[4] Holding the inlet connection, tilt the filter housing sideways in order to disengage the front half of the housing from the rear. Note that the inlet side of the filter housing has the word "Inlet" stamped on the inside and that two tabs engage slots in the other half of the housing.

[5] Remove and discard the old filter (the white Teflon disk). Install the new filter using tweezers or gloves. Avoid touching the surface of the filter with your bare fingers.

[6] Reinstall the inlet side of the filter housing making sure that the two tabs engage the slots in the other half. Secure the filter with the metal plate and four screws.

[7] Leak check the Photometer as described below.

[8] Reattach the sample inlet.

Leak Check

Leaks can develop due to the deformation of seals or by loosening of connections due to vibration. A leak within the Photometer assembly or in the pneumatic path before the Photometer can result in erratic or low span readings. A leak between the Photometer and pump can result in low flow or erroneous pressure indications.

The following procedure may be followed to test the Photometer sample path for leaks:

[1] With the Model 4010 powered off and disconnected from power, remove the cover from the unit and put it aside.

[2] Using a 9/16” wrench, disconnect the hose connected to the fitting labeled Vacuum Source as shown on Figure 9-9.

[3] Using a 9/16” wrench, remove the 3-Way valve connection from the sample tee and plug the horizontal port with a suitable cap. Refer to Figure 9-9 for details.

[4] Apply the vacuum source and monitor for any loss. The vacuum source should read approximately 15 inHg and the system should maintain the initial value for a few minutes to insure system integrity.

[5] If there appears to be a leak, make sure that the sample column bushing and fittings are pressing the o-rings sufficiently to maintain a proper seal. The compression on the o-rings can be changed by screwing the fitting side of the sample column out. Do not adjust the placement of the bushing or fitting by loosening the set screws unless it is absolutely necessary for proper 0-ring compression.

[6] Replace all connections and place the cover back on the calibrator.

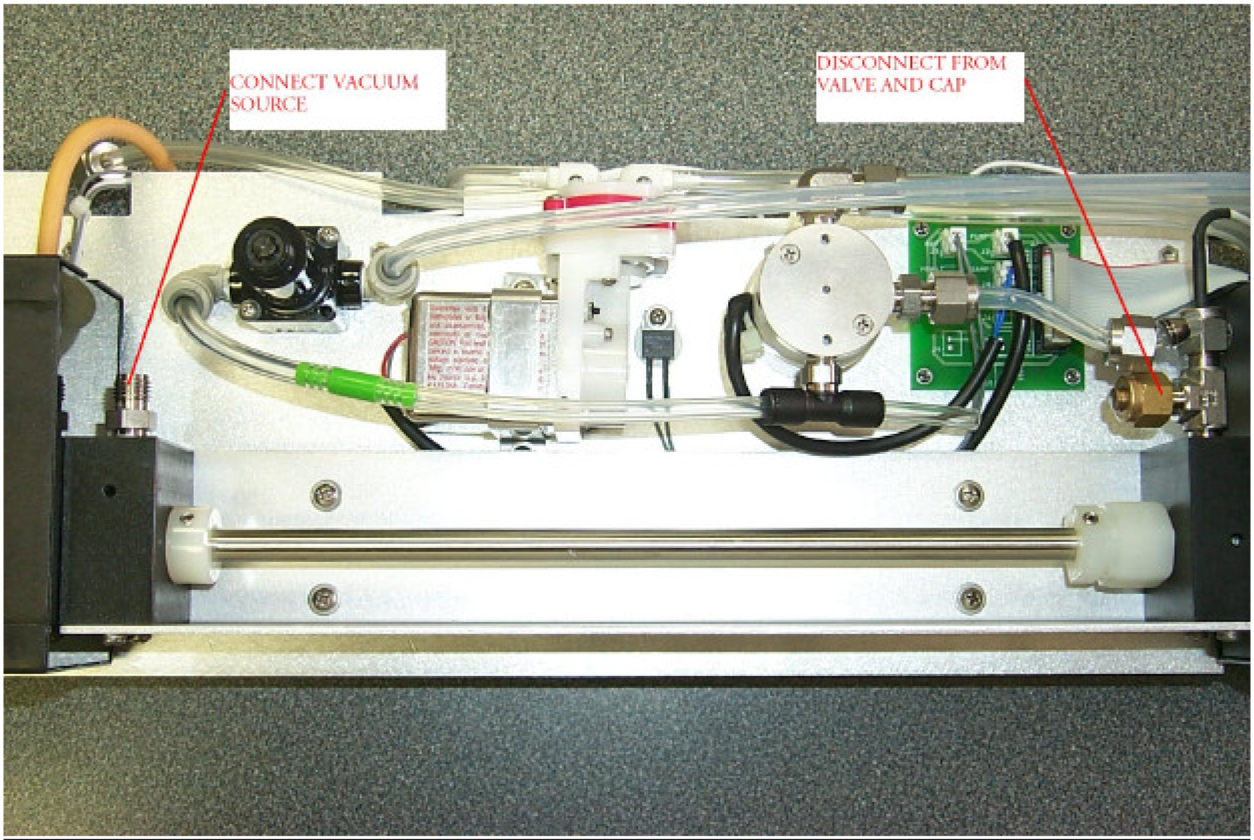


Figure 9-9 Photometer, Leak Check Setup

Photometer Flow Check/Adjustment

The reference air for the photometer is supplied from the same source as the diluent air for the dilution system. This is split from the dilution stream prior to entering into the dilution system. High or low flow entering the sampling stream can cause the photometer to read erratically or off depending on the amount of flow.

The reference air is regulated by a precision pressure regulator and orifice to 1400 SCCM or 1.4 Liters. The following procedure can be used to determine the flow of the zero air and to adjust the regulator if the flow is incorrect:

[1] With the Model 4010 powered off and disconnected from power, remove the cover from the unit and put it aside.

[2] Disconnect the hose that is connected to the tee fitting located on the sample valve. The tee for the valve is quick disconnect fitting, so pressing the collar inward

and pulling the tube out will remove it without the use of tools. Refer to Figure 9-10 for details.

[3] Connect a flow standard to the output of the regulator. The flow standard must be capable of reading at least 1.4 Liters or 1400 SCCM. Refer to Figure 9-10 for details.

[4] Apply 35 PSI of zero air to the port labeled “AIR IN” on the rear panel of the photometer.

[5] The flow standard should be reading 1.4 L or 1400 SCCM after the zero air is applied.

[6] If the flow is reading high or low, then the pressure regulator will need to be adjusted. Adjustments can be made by rotating the screw located on the top of the regulator. Allow enough time for the flow standard to stabilize before re-adjusting.

[7] Replace all connections and place the cover back on the calibrator.

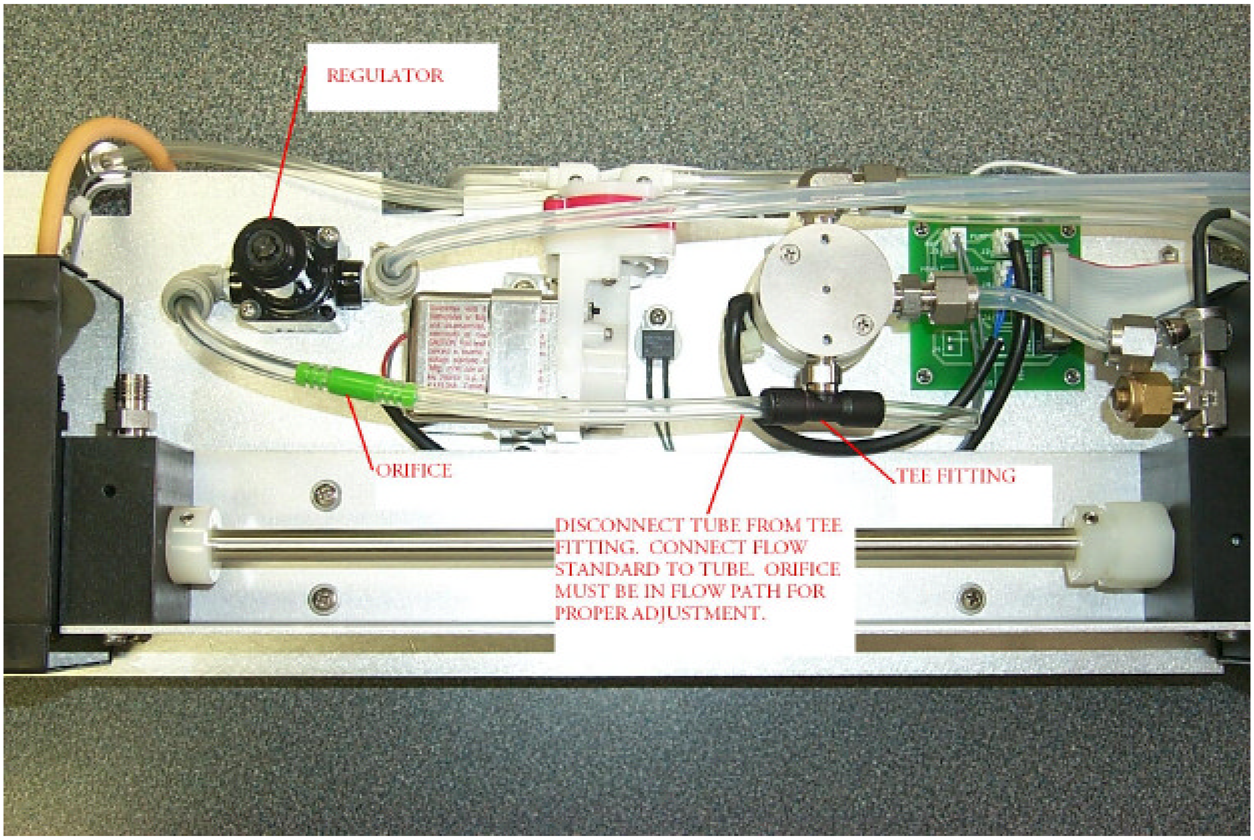


Figure 9-10 Photometer, Flow Check/Adjustment

Schematics

4010 Pneumatic Flow Diagram

ACAD FILE NUMBER	REVISIONS					
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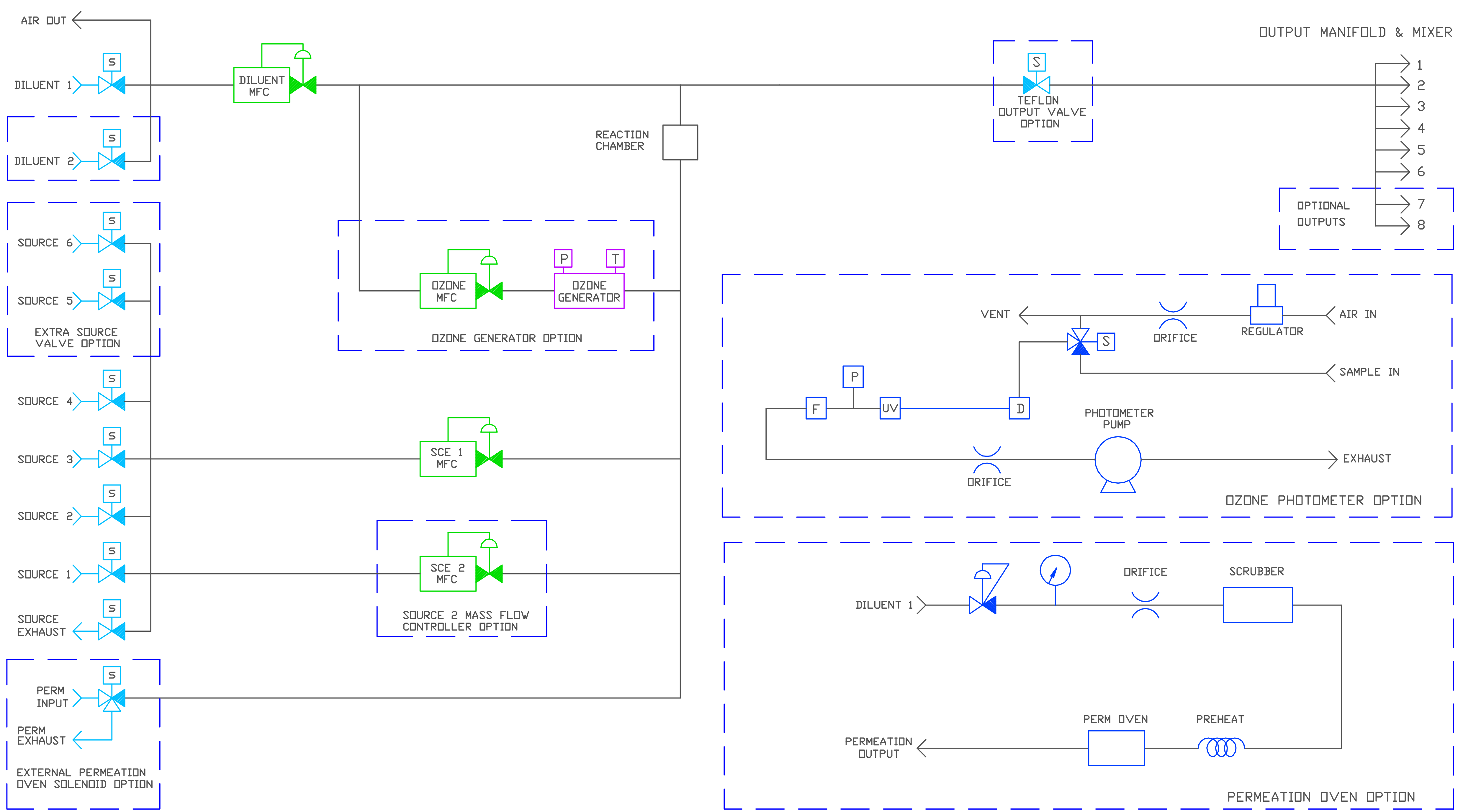

APPROVED	DATE	APPROVED	DATE
DRAWN BY: M.GORDY	10/7/04	CAD CHECK BY:	
ENGINEERED BY: M.GORDY	10/7/04	QUALITY CONTROL	
ELECTRICAL CHECK		STRUCTURAL CHECK	
KIT ENGINEERING		ISSUED BY: D.GORDY	10/7/04

DO NOT SCALE THIS DRAWING

SABIO ENGINEERING, INC.
323 WEST 8TH ST., P.O. BOX 651
PH. (512) 869-0544 FAX (512) 869-0993

FLOW DIAGRAM, MODEL 4010

SIZE B | DWG. NO. 01350 | REV A
SCALE 1:1 | SHEET 1 OF 1

WARRANTY

Sabio Instruments, Inc. warrants that its products will be free from defects in materials and workmanship under normal use and service for the current established warranty period of twelve months for the Model 4010. Sabio Instruments obligation under this warranty shall not arise until the Buyer returns the defective product, freight prepaid to Sabio Engineering's facility or another specified location. Sabio Instruments, Inc. will at it's option replace or repair free of charge the defective product.

LIMITATIONS ON WARRANTY

The warranty set forth above does not extend to and shall not apply to:

1. Products which have been subject to abuse, misuse, neglect, accident, power reversal or improper installation.

2. Products which have been repaired or altered by other than Sabio Instruments, Inc. personnel, unless Buyer has properly altered or repaired the products in accordance with procedures previously approved in writing by Sabio Instruments, Inc.

The warranty and remedies set forth above are in lieu of all other warranties expressed or implied, oral or written or by operation of law, statutory or otherwise.

SERVICE POLICY

1. If a product fails during the warranty period, it will be repaired or replaced free of charge. For out of warranty repairs, the customer will be invoiced for repair charges at the current standard labor and materials rates.

2. Customers that return a product for repairs within the warranty period, and the product is found to be free of defect, may be liable for the minimum current repair charge.

3. In certain conditions, Sabio Instruments, Inc. provides on site warranty repairs. For more information in this regard contact the factory.

RETURNING A PRODUCT FOR REPAIRS

Upon determining that repair services are required, the customer must:

1. Obtain an RMA (Return Material Authorization) from Sabio Instruments, Inc., 512/869-0544.

2. If the request is for an out of warranty repair, a purchase order or other acceptable information must be supplied by the customer.

3. Include a list of problems encountered along with your name, address, telephone number and the RMA number.

4. Package the product in an appropriate container for shipping. It is recommended that the original container, which is especially made to fit the product, be used in this event.

5. Write the RMA number on the outside of the shipping container.

6. For products under warranty the customer must pay shipping to Sabio Instruments, Inc. Sabio Instruments, Inc. will pay for return shipping to the customer via ground transportation.

NOTE: PRODUCTS RETURNED TO SABIO INSTRUMENTS, INC. FREIGHT COLLECT OR WITHOUT AN RMA NUMBER CANNOT BE ACCEPTED AND WILL BE RETURNED FREIGHT COLLECT.

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